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Evaluation of the Performance Indicators for Safety reuse of Treatment Greywater in Northern West Bank

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٢٠١٦

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Dedication

For my Mother, the soul of my Father

To my dear husband Dr Abdulla Alimari who supported and helped me in my research

To my kids (Tala, Essam,Tuleen and Jana)

To my Sisters and Brothers

To everyone who helped and supported me in my research with love and respect.

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الإقرار

أنا الموقع/ة أدناه ، الرسالة التي تحمل العنوان:

An Integrated Evaluation of the Performance Indicators for Safety reuse of Treatment Greywater in North West Bank

اقر أن ما اشتملت علية هذه الرسالة ،إنما هي نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وان هذه الرسالة كلها ، أو أي جزء منها لم يقدم من قبل لنيل أية درجة ، أو لقب علمي ،أو بحثي لدى أية مؤسسة تعليمية،أو بحثية أخرى.

Declaration

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

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Date:	**التاريخ :**

Table of content

List of Table

Table of Figure

ABBREVIATIONS

EC	Electrical Conductivity
EQA	Environment Quality Authority
GW	Grey Water
GWTP	Grey Water treatment plant
ICRDA	International Center for Agricultural Research in the Dry Area
NARC	National agriculture research center
NGOs	Nongovernmental organizations
PSI	Palestinian Standards Institute
PWA	Palestinian Water Authority
SAR	Sodium Adsorption Ratio
TDS	Total Dissolve solid
TWW	Treated wastewater
WHO	World Health Organization
MENA	Middle east and north Africa

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Abstract

The conventional groundwater sources supply in Palestine is vulnerable and scarce. Among potential alternative sources of supply is greywater which usually comprises ٥٠–٨٠٪ of residential wastewater.

The aim of this research is to assess the long and short term impacts and social acceptance of onsite GWTPs. Performance indicators were used for assessing the quality and efficiency of the execution of treated greywater reuse stations in the North West Bank. Six home gardens from Jenin and Tubas governorates used treated greywater (constructed wetland system) for fruit tree (citrus and olive) and fodder (sorghum) plantations were assessed. A field survey (Questionnaires) were designed for the beneficiaries. Data was collected and analyzed using Excel and SPSS package. The short term indicator included greywater quality parameter before and after treatment during the period from June and July ٢٠١٥.

pH , TDS, Na^{+} ,$Ca^{٢+}$,Cl^{-} ,BOD ,$PO٤^{٢+}$ and $SO_{٤}^{٢-}$fall within the Palestinian standard for treated wastewater (٢٠١٢). The average were ٧.٥, ١٠٢٤.٢٧, ١٢٨.٢, ٦٥.٦, ٢٢٤, ١٧٨, ٧.٦٩ and ١٣٩ respectively. While

$Mg^{٢+}$,$NO^{-}_{٣}$and COD were higher than the standard. The average were ٢٨٨.٣, ٧٧.٨ snd ٤٠٠.٨respectively

The long term indicator includes greywater treatment result in ٢٠١١ carried out by North Agriculture Research Centre NARC compared with the greywater treatment results in the year ٢٠١٥ and the impact of irrigation with treated greywater on chemical properties of the soil.

During ٢٠١٥, the efficiency of total coliform removal was ٣٣.٣٪ compared to ٨٧ % in ٢٠١١. The decrease was ٥٣.٣٪. In ٢٠١٥, the efficiency of E .coli was ٣٧.٣٪ compared to ٥٥.٣ % in ٢٠١١. The decrease was ١٨٪. The efficiency of BOD was ٧٠.٨ in ٢٠١٥ compared to ٧٥.٨ % in ٢٠١١. The decrease was ٥٪. The efficiency of EC was ٩.٨ % in ٢٠١٥ compared to ٢٧.٣ % in ٢٠١١. The decrease was ١٧.٥٪. The TDS decrease ١٦.٣ % . The important parameters as BOD, TDS, EC, and E .coli showed a decrease in the efficiency of the stations by time, but it remains within the accepted Palestinian standards .

Three soil samples were collected from the garden irrigated with treated graywater at depth ٠-٣٠cm and ٣٠-٦٠cm copared with the control irrigated with fresh water. The results of the pH was ٦.٦٧ and for Ec was ٢.٦٥ which remains within the accepted Palestinian standards. The average concentrations of Zn, Cu, Cr and Mn were ٣.٣, ٠.٤٤, ٠.٦٩ and ٥.١٦ respectively in soils were not significantly higher than control. The results also do not show any relationship between long time application of greywater and heavy metals accumulations in the soil. In total, ٦٠٪ of individuals do not have information about greywater. The study shows that nearly ٧٦٪ of the respondents face a water shortage and the same percent reported that water prices being a major constraint they have to deal with. The average number of seepage times is ٤.٦ and the average cost is ٩٥ NIS per each time. This reflects the high cost of the seepage. Moreover, ٣٣٪ of treatment units' owners stated that the units need regular maintenance. About ٧١٪ of unit's owners stated that the units increase crop production in the home garden. In addition, ٨٩ % of them indicated the decrease in units efficiency by time. These results are inagreement with chemical analysis. The economic factor (٣٧٪) was limiting factor for dissemination of the treatment units among the communities. People's satisfaction with the applied GWTPs was very promising, as the majority ٧١.٤٪ of GWTPs beneficiaries are satisfied with the treatment stations.

Chapter one

Introduction

١.١ Introduction

Water supply in Palestine is one of the most serious problems facing Palestinian society. The lack of water resources and the competition between different uses, i.e. domestic, agricultural and industrial is increasing demand with time. The limitation of water resources for the Palestinians is mainly due to the Israeli occupation authorities laws and practices. Israeli settlements control water resources, waste a lot of fresh water quantities, and produce a lot of wastewater which is disposed on Palestinian land contaminating the soil and the limited water resources available for Palestinians(Al-Jayyousi, ٢٠٠٣).. Cesspits used by Palestinians to dispose their wastewater are a major source of pollution to water resources. These cesspits also form a large burden on the income of the Palestinian families, where some families spend about ٢٠٪ of their monthly income to manage water and wastewater at house level (PHG, ٢٠٠٧). Palestine is one of the most water-poor countries of the Middle East due to natural and artificial constraints. It is also one of the most highly populated, a fast developing country in the region and is thought to be under significant environmental stress. Urgent actions are required to mitigate this situation, including environmental protection and the utilization of the available non- conventional water resources, precisely, the utilization of the treated wastewater. At present, water needs exceed the available water supply. The gap between water supply and water demand is steadily growing and is calling for the adoption of the integrated water resources management approach and the mobilization of any additional conventional and non-conventional water resources. Treated wastewater is seen as one of the promising solutions that can assist in partially filling the gap of the growing needs for water (Mahmoud and Mimi, ٢٠٠٨). Most of the wastewater is generated from households. The domestic wastewater usually contains disease- causing pathogens and contain heavy metals or toxic components. Controlled treatment of wastewater is essential to reducing potential pollution of surface or groundwater. In addition, treated wastewater can be an excellent source for irrigation purposes. Food security is at risk because the amount of fresh water that can form sustainable supplies to people is reaching its limits because of Israeli restrictions, which is extended to whole of Palestine. The current main source of income is agriculture for the majority of the population. A state of conflict and competition over land and water resources has arisen and continues to prevail. This has had an adverse impact on the living and food security conditions of the household. Properly treated wastewater can be reused to reduce the demand on high quality freshwater resources. Wastewater recycling increases the availability of water supply, reduces vulnerability to droughts and enables greater human benefit with less use of fresh water. By reducing the need for fresh water and wastewater discharges, water recycling has the potential to make a substantial contribution to meeting human water needs, and reducing mankind’s impact on the world’s water environment. As in many developing countries, sanitation tends to receive less attention and fewer financial resources than water supply. This leads to a lack of maintenance even for existing wastewater treatment plants (WWTP), as is the case, for example, in Morocco and Algeria where more than half of the WWTP are not functioning properly (Coppola et al., ٢٠٠٤). In many small-to-medium-sized communities, wastewater treatment requirements are met using conventional onsite septic tanks, with effluent being disposed into the groundwater. In Palestinian rural areas the sewage problem is even more complicated and wastewater management at all stages is inadequate. The existing on-site sewage disposal in rural areas (the majority of the households in the West Bank villages use septic tanks and cesspits) does not accommodate the vast increases in wastewater generated by the population. Thus, untreated sewage contaminates ground water and agricultural fields and causes critical community and environmental health risks. Palestinian NGOs with international funds are the main organizations involved in the construction of wastewater treatment plants in the rural areas in the West Bank.

Water scarcity in the West Bank poses a critical constraint to further expanding, or even maintaining present irrigated areas. There is an increasing demand for agricultural water use to be restricted in favor of other water consumers, such as local communities and industry. The West Bank is that part of the Palestinian areas that were occupied by Israel in ١٩٦٧ war and is at present partially under Palestinian Authority. Since ١٩٦٧ Israel has controlled water resource and management in Palestine, including the licensing, operation, administration of wells and prohibition of new well drilling without authorization. In fact, Palestinians in the West

Bank are limited to ١٢٥ (million cubic meters) MCM of their water resources per year for all purposes. From this quota, ٩٣ MCM are used for agriculture to irrigate around ٦ percent of the Palestinian cultivated area in the West Bank (١.٦٨ million dunums, ١ dunum = ١٠٠٠ square meters). In contrast, Israel enjoys a plentiful supply of water (١٢٥٢ MCM) to irrigate ٢,١٧٧,٥٠٠ dunums that form ٦٢ percent of its cultivated land (Arij,٢٠١١) .

١.٢ Performance indicator

A performance indicator is a measurement survey to evaluate progress toward periodic achievement of the efficiency or productivity of a process that reflects the outcome or results of the process activities (Fitz-Gibbon ١٩٩٠). Performance indicators may be considered as providing key information needed to define the efficiency and performance of a facility or a system (Calor Taylor ١٩٩٧). Performance indicators (PI) are evaluation tools that measure potential advantages and restrictions within the preparation and implementation of greywater reuse projects. The final verdict and success of a water reuse task depends on many different aspects such aseconomic, technical, geological, sociological, environmental, political, and quality as well as risk issues. The purpose of developing these performance indicators of treated greywater reuse in the north west bank is to create impact estimation indicators of the project interventions on farming systems and the environment (land and water resources). Socio-economic, technical, and environmental aspects leading to safe and productive use of wastewater for crop production systems at the farm level and similar use of greywater at the household level .

Efficiency is the extent to which the resources of an undertaking are used to provide the service by maximizing delivery and minimizing misuse. Waste water and greywater reuse for agricultural purposes in Palestine is being slowly introduced for a number of reasons (Houshia ٢٠١٢, ٢٠١٣). Development of agriculture in north west bank (Palestine) is especially troubled by a number of challenges, the most important of which is constrained water resources since, as an arid and semi-arid country, it receives very little rain (PWA). This in turn limits the extent of rain-fed agriculture. Irrigated agriculture still has room for growth; however, it must compete with other demands for the limited available water mainly from domestic and industrial consumers. Thus, farmers understand that it is vital that all available water resources in the country be put to the most beneficial economic use, including the use of treated waste and greywater.

١.٣ Research Questions

What is the impact of short and long term use of treated graywater on Economic, social and physical aspect ?

Chapter two
Literature review

٢.١ Literature review

Many studies on wastewater address socioeconomic and political issues associated with its use for agriculture. Decentralized greywater management in Japan, North America and Australia are considered the highest ranked globally. In areas with low population densities, such as throughout North America and Australia, greywater reuse is common practice due to water scarcity and lack of centralized treatment facilities. Since greywater is a reflection of household activities, its main characteristics strongly depend on factors such asliving standard, cultural habits, type of household chemicals used,household demography, etc. In Cyprus, a study on greywater reuse indicates a ٣٦٪ reduction in water usage when household greywater is reused. The generated amount of greywater greatly varies as a function of the dynamics of the household. It is influenced by factors such as existing water supply systems, and infrastructure, number of household members, age distribution, lifestyle characteristics, typical water usage patterns etc. Most system failures are caused by inappropriate operation and maintenance, sometimes also resulting from a lack of system understanding by the owners (Sandec, ٢٠٠٦). Framers and common public of the MENA (Middle East And North Africa) countries have limited knowledge and unclear perceptions towards wastewater reuse and the prevailing water shortage. Many people believe that Islamic religion prohibits reuse of treated wastewater. Conversely, Islamic religion supports water demand initiatives as well as reuse of treated wastewater that does not have negative impacts on public health. Joint efforts are needed from academic, governmental, nongovernmental, and aid institutions on developing awareness and appropriate educational programs and initiatives that improve public knowledge and perceptions (AbuMadi and Al-Sa'ed, ٢٠٠٩).

A decentralized system employs a combination of onsite and/or cluster systems and is used to treat and dispose of wastewater from houses and businesses close to the source. Decentralized wastewater systems allow for flexibility in wastewater management, and different parts of the system may be combined into "treatment trains," or a series of processes to meet treatment goals, overcome site conditions, and to address environmental protection requirements. Managed decentralized wastewater systems are viable, long-term alternatives to centralized wastewater treatment facilities, particularly in small and rural communities where they are often most cost-effective. These systems already serve a quarter of the population in the U.S. and half the population in some states. They should be considered in any evaluation of wastewater management options for small and mid-sized communities (Pipeline, ٢٠٠٠).

٢.٢ Greywater in Palestine

Scarcity and misuse of water are serious and growing threats to sustainable development and protection of the environment. Human health and well fare, industrial development, food security, and the ecosystems on which they depend are all at risk, unless water and land resources are managed more effectively than they have been in the past to meet the increasing population demands (Al-Jayyousi, ٢٠٠٣). With increased population growth and development in Palestine (PCBS, ٢٠١٠), the conventional groundwater sources supply is becoming increasingly vulnerable and scarce. This growth, combined with recent years of low rainfall, political turmoil, has resulted in increasing pressure on water supplies in Palestine(Amjad, ١٩٩٩). To circumvent this problem, an alternative water resource plan is being advocated. Among these potential alternative sources of supply is greywater(Faruqui and Al-Jayyousi. ٢٠٠٣). Greywater from a single household, if treated Properly, can be considered a resource and can be used on-site for garden irrigation, washing machines, toilet flushing, and other outdoor uses(AlHamaiedeh and Bino. ٢٠١٠). Garden irrigation and toilet flushing, for example, do not need water with drinking quality (Bino, Al-Beiruti and Ayesh, ٢٠١٠). Greywater refers to the wastewater generated from kitchens, bathrooms and laundries, not black water, which is waste water containing human excrement. Greywater can be used untreated, or it can be treated to varying degrees to reduce nutrients and disease-causing microorganisms. The appropriate uses of greywater depend on both the source of greywater and the level of treatment. The potential health risks associated with greywater recycling when it has been sourced from a multi-dwelling or commercial premises are considered potentially greater than those associated with greywater recycling within single domestic premises. Therefore, greywater recycling must always occur in a safe and controlled manne (Al- Hamaiedeh, ٢٠١٠). In the northern part of the Palestine (West Bank), there are many communities with sparse population and large landscape area that have not permanent water resources. For agriculture and domestic purposes these communities get their water from either the seasonal rainfall or they resort to trucking water in tanks from a distant source. Those towns and villages lack proper sewage system. The reuse of grey-water at household scale has become an important tool to enhance water efficiency, which enables them to use for water for multi-purpose irrigation.

The generated amount of greywater greatly varies as a function of the dynamics of the household. Its influence by factors such as infrastructure, existing water supply systems, age distribution, number of household members, typical water usage patterns, and life style characteristics etc. Reuse of treated greywater in irrigation can significantly contribute to reducing water usage and increasing food security. Greywater reuse is especially recommended in areas facing water stress such as the Middle East and Sub-Saharan Africa. Most system failures are caused by improper operation and maintenance, sometimes also resulting from a lack of system understanding by the owners (Sandec, ٢٠٠٦). Greywater contains impurities and micro-organisms derived from personal and household cleaning activities. While bathroom and laundry water are relatively moderate, kitchen water often needs special attention because it is contained with organic matter from food wastes. Greywater is distinct from black water (from the toilet or urinal) as there are fewer environmental and health risks associated with its use. If used wisely and appropriately, Greywater including its separation, containment and use can be a simple home-based water demand management strategy that has benefits at the household level as it can be considered as an alternative water resource to optimize productivity (Redwood, ٢٠٠٧). Greywater thus does not contain the same elevated level of pathogens (WHO, ٢٠٠٦).

Greywater should be regarded as a valuable resource and not as a waste. Despite the described inadequate greywater management risks, greywater has, nevertheless, a great potential to reduce the water stress currently faced by regions in the world. Reuse of greywater for irrigating home gardens or agricultural land is widespread, especially in regions with water scarcity or high water prices such as the Middle East, Latin America and parts of Africa. Greywater is thus perceived and recognized as a valuable resource (Sandec, ٢٠٠٦). Greywater in contrast to common perception, may be quite polluted, and thus may pose health risks and negative aesthetics (i.e., offensive odour and colour) and environmental effects (Diaper et al., ٢٠٠١). Onsite greywater reuse is a feasible solution for decreasing overall urban water demand, not only from an environmental standpoint, but also from economic profitability under typical conditions (Friedler and Hadari, ٢٠٠٥). One strategy may be to encourage more on-site sanitation rather than expensive transport of sewerage to centralized treatment plants: this strategy has been successful in Dakar, Senegal, at the cost of about ٤٠٠ US$ per household (World Bank, ٢٠٠٥). A series of projects on greywater treatment and reuse have been implemented in Lebanon, Jordan and Palestine. The projects explored water management techniques, simple technological innovations and creative agricultural practices for greywater reuse at the household level. Households used the recycled water to irrigate crops with associated social and economic benefits. Officials monitored the quality of the greywater used for irrigation over time and concluded that the system met WHO's standard for restricted irrigation (AWC, ٢٠٠٦)

٢.٣ Greywater definitions

Greywater is washing water from bathtubs, showers, bathroom washbasins, clothes washing machines and laundry tubs, kitchen sinks and dishwashers. (Del Porto and Steinfeld, ٢٠٠٠)

Whereas NSW Health(٢٠٠٠) defined greywater as a wastewater which is not grossly contaminated by feces or urine, i.e. the wastewater arising from plumbing fixtures not designed to receive human excrement or discharges and includes bath, shower, hand basin, laundry and kitchen discharges.

Greywater safer (٢٠٠٤) defined greywater as a wastewater generated in the bathroom, laundry and kitchen, and is therefore the components of wastewater which have not originated from the toilet.

Greywater arises from domestic washing operations. Sources include waste from hand basins, kitchen sinks and washing machines, but specifically exclude black water from toilets, bidets and urinals. (Jefferson et al., ٢٠٠١)

Greywater is defined as all wastewaters generated in the household, excluding toilet wastes. It can come from the sinks, showers, tubs, or washing machine of a home. (Casanova et al., ٢٠٠١)

٢.٤ Greywater sources

Greywater can be divided into several groups, according to the source of the greywater. In this section work the structure shown in Table (١) is used. Table (١) gives a first overview of the general characteristics of the three main greywater source types.

Table (٢.١): Untreated greywater characteristics from each source

Water sources	Characteristics
Laundry	Biological: high in biochemical oxygen demand (BOD). Microbiological: variable thermotolerant coliform loads Chemical :ammonia, boron, nitrogen , phosphate, sodium, surfactants, and from soap powders and soiled clothes. Physical: turbidity, high in suspended solids and lint.
Bathroom	Biological: lower levels of concentrations of biochemical oxygen demand(BOD). Microbiological: lower levels of thermotolerant coliforms Chemical: cleaning chemicals, hair dyes ,shampoo, soap and toothpaste. Physical: hair, high in suspended solids, and turbidity.
Kitchen	Biological: high in biochemical oxygen demand(BOD). Microbiological: variable thermotolerant coliform loads. Chemical: detergents, cleaning agents. Physical: fats, grease, food particles, oils, turbidity

Source: **(Queensland, ٢٠٠٢)**

The most significant pollutants of greywater are powdered laundry detergents. These contain high salt concentration and in many cases still contain phosphorus, and are often very alkaline. Long term garden reuse of laundry water containing high salt and phosphorus concentrations can lead to salt accumulations in the soil and stunting of plants with low phosphorus tolerance. Regions with regular rainfall may not suffer salt build-ups due to leaching of salts from soil after rain. There are several alternatives to using powdered laundry detergents. These include liquid detergents (which are generally much lower in salt content), pure soap flakes (e.g. Lux soap flakes) or ceramic disks (e.g. Tri-Clean laundry disks). High strength cleaners should be avoided in the home, as they are often toxic to both people and the environment. If caustic cleaners are washed down the drain, they are likely to kill beneficial treatment bacteria in soils if greywater is reused for onsite garden irrigation (Marshall, ١٩٩٦).

٢.٥Composition of household greywater

Table ٢.٢ presents the microbiological quality (the number of thermotolerant coliforms) of greywater from various sources in a residential dwelling. Thermotolerant coliforms are also known as faecal coliforms (expressed as colony forming units per ١٠٠ ml) and are a type of micro-organism which typically grow in the intestine of warm blooded animals (including humans) and are shed in their millions to billions per gram of faeces. A high faecal coliform count is undesirable and indicates a greater chance of human illness and infections developing through contact with the wastewater.

Table (٢.٢) : Treated greywater biological Characteristics

Characteristic	Unit	limits
Escherecia coli	cfu/١٠٠ml	**
Intestinal Helminthes Eggs	egg/ L	≤١

Source: Water -Reclaimed greywater in rural areas- Jordanian standards (٢٠٠٨)

The chemical and physical quality of treated greywater is shown in Table ٢.٢. The high variability of the greywater quality is due to factors such aswater use efficiencies of appliances, individual habits, source of water and fixtures, products used (detergents,soaps, shampoos) and other characteristics.

Table (٢.٣):Physical and Chemical Characteristics of Treated greywater.

Characteristic	Unit	limits
BOD٥	mg/l	٣٠٠
COD	mg/l	٥٠٠
TSS	mg/l	١٥٠
pH	Unit	٦-٩
NO٣⁻	mg/l	٥٠
T-N	mg/l	٧٠
Turbidity	NTU	٢٥
Phenol	mg/l	٠.٠٥
MBAS	mg/l	٢٥
TDS	mg/l	١٥٠٠
T-P	mg/l	١٥
Cl^-	mg/l	٣٥٠
SO٤⁻	mg/l	٥٠٠

Source: Water -Reclaimed greywater in rural areas- Jordanian standards (٢٠٠٨).

Wastewater Reuse Water reuse can be planned through specifically designed projects to treat, store, convey and distribute treated wastewater for irrigation. Examples of planned reuse can be found in Tunisia. Indirect reuse can also be planned as in Jordan and Morocco, where treated wastewater is discharged into open watercourses. Wherever available, farmers prefer to rely on freshwater, which is usually very cheap and socially acceptable. But if no other source of water is available, especially in arid and semiarid regions such as the case in the Middle East, farmers throughout the region would be encouraged to use wastewater for irrigation (EMWATER, ٢٠٠٤). Recycling wastewater for food production is less common than using wastewater for municipal uses, golf courses, or wetlands. Yet, it is common in poorer countries of the world where water is simply unavailable or where the economic incentive to reuse is substantial. It is estimated that ٢٠ million farmers worldwide uses untreated or partially treated wastewater (WHO, ٢٠٠٨). There are several theoretical advantages of using wastewater: It is available for ٣٦٥ days a year, it comes in reliable and predictable quantities, quantities are not normally reduced during a drought, it can be made available cheaply. Unfortunately, in Palestine policy to promote reuse attempts so far have not been conclusive (World Bank, ٢٠٠٩). Oron et al. (١٩٩٩) identified two basic requirements for utilization of wastewater as a solution for water shortage problems whilst minimizing the health and environmental risks: (i) the need for comprehensive wastewater collection systems, and (ii) the need for well-operated wastewater treatment facilities. The most important barriers for reuse of reclaimed wastewater in the MENA region, the reuse of reclaimed wastewater are often recognized after the design and implementation of treatment plants. Due to low tariffs of irrigation water, farmers are not attracted to replace freshwater with reclaimed wastewater, framers and common public of the MENA countries have limited knowledge and unclear perceptions towards wastewater reuse and the prevailing water shortage (Abu-Madi and Al-Sa’ed, ٢٠٠٩). Palestine has its own standard “The sixth draft of treated wastewater standard”, which has been prepared by a special technical committee. The main components of the standard are as elaborated in Table (٢-٤).The standard consists of a combination of factors that influence the use treated wastewater in several purposes, and reclaimed wastewater is classified into ٤ groups as shown in the Table (٢-٤) below.

Table (٢.٤)Reclaimed wastewater classification, (Sixth draft of treated wastewater standard).

Class	Water Quality Parameters			
		BOD٥	TSS	Fecal coliforms
Class A	High quality	٢٠ mg/l,	٣٠ mg/l	٢٠٠ MPN/١٠٠ ml
Class B	Good quality	٢٠ mg/l,	٣٠ mg/l,	١٠٠٠ MPN/١٠٠ ml
Class C	Medium quality	٤٠ mg/l,	٥٠ mg/l,	١٠٠٠ MPN/١٠٠ml
Class D	Low quality	٦٠ mg/l,	٩٠ mg/l,	١٠٠٠ MPN/١٠٠ ml

Source: Palestinian Standards Institute (PSI, ٢٠١٠)

٢.٦ Trace elements in the environment

Trace elements are released into the environment from the natural weathering of rocks and minerals from various sources related to human activity. Although the concentration of these elements occurring in nature is generally low, they may directly or indirectly affect the chemical composition of foodstuff and animal feed, potable water supplies and airborne particulates and dust. The practical implication of trace elements in the environment relates to their availability for plant uptake from the soils and their release into water systems. The content of trace elements in soil is an indication of possible excesses or deficiencies for plant nutrition and ultimately animal and human health (Haluschak et al., ١٩٩٨).

٢.٧ Factors affecting the concentration and distribution of trace elements in soil

The concentrations of trace elements in the soil and water is the result of interaction between various factors affecting geological weathering and soil forming processes (Haluschak et al., ١٩٩٨).local soil and hydrological conditions affecting processes of soil formation, soil development and availability of trace elements for plant uptake. Heavy metal content in soils irrigated by treated wastewater soil is an essential natural resource but with time degradation will be increased due to the deposition of pollutants. The study of Maldonado (٢٠٠٨) demonstrated that among the variables, soil type was the only factor showing a statistical difference. It was noted that concentrations of boron, chromium, copper, iron and nickel concentrated in deeper soil layers while cadmium, potassium, sodium, and lead showed the opposite effect.

It was also noted that organic material is an important variable and that it can influence the mobility of metals in those areas where high concentrations, coincide with constant irrigation. Clearly, the area has been constantly exposed to certain health hazardous metals. More attention is recommended, even though at this time a wastewater treatment plant has been built and partly treated water is used to irrigate the crops (Maldonado et al., ٢٠٠٨). In contaminated soils, heavy metals such as arsenic, cadmium, chromium, copper, lead, mercury and zinc are common (Raymond et al., ٢٠١١).

٢.٨ Long term impact of treated greywater reuse on chemical and physical soil characteristics

In Jordan, the use of treated greywater (GW) for irrigation in home gardens is becoming increasingly common. According to a study conducted by Mutah University and The Inter-Islamic Network on Water Resources Development and Management, Amman, Jordan on Effect of treated greywater reuse in irrigation on soil and plants, treated greywater produced from ٤-barrel and confined trench treatment units were used for irrigation of olive trees and some vegetable crops. The quality of treated and untreated GW was studied to evaluate the performance of treatment units and the suitability of treated GW for irrigation according to Jordanian standard. Effect of treated GW reuse on the properties of soil and irrigated plants at Al-Amer villages, Jordan, has been investigated. The results showed that salinity, Sodium Adsorption Ratio (SAR), and organic content of soil increased as a function of time, therefore leaching of soil with fresh water was highly recommended. The chemical properties of the irrigated olive trees and vegetable crops were not affected, while the biological quality of some vegetable crops was adversely affected (Al-Hamaiedeh et al., ٢٠١٠). Glasshouse experiments were conducted to examine the effects of greywater irrigation on the growth of silver beet plants, their water use and changes in soil properties. Results showed that greywater irrigation had no significant effect on soil total Nitrogen and total Phosphorous after plant harvest, but there were significant effects on the values of soil pH and EC. Furthermore, there were no significant effects of greywater irrigation on plant dry biomass, water use and number of leaves. Irrigating alternate with potable water and greywater could reduce some of the soil health risks associated with the reuse of greywater (Pinto et al., ٢٠١٠).

A controlled study of the effect of greywater (GW) irrigation on soil properties was conducted by Micheal et al., (٢٠١٠), Containers of sand, loam and loess soils were planted with lettuce, and irrigated with fresh water, raw artificial greywater or treated artificial greywater. Greywater was treated using a recalculating vertical-flow constructed wetland. It was demonstrated that raw artificial greywater significantly increased the development of hydrophobicity in the sand and loam soils, as determined by water droplet penetration time. No significant changes were observed for the loess soil under all treatments. This study demonstrates that treated greywater can be effectively used for irrigation without detrimental effects on soil or plant growth. Hamaiedeh (٢٠١٠) showed that there is no increase in the rate of water born diseases after greywater reuse for irrigation. The accumulation of heavy metals in the soil was insignificant and the uptake of these metals by the irrigated plants did not occur.

Greywater contains significant concentrations of materials with potential negative environmental and health impact, such as salts, surfactants, oils, synthetic chemicals and microbial contaminants (Gross et al., ٢٠٠٧).

Chapter three
Methodology

٣.١ Methodology

٣.١.١ introduction to Performance indicators

Performance indicators were considered in this study for an integrated evaluation of the performance indicators for safety reuse of the treatment of gray water in Northern west bank. Performance indicators for greywater reuse are qualitative and quantitative indicators for assessing the quality and efficiency of the execution of treated greywater reuse projects in the North West Bank. The Performance indicators are divided into social, economic, and environmental indicators.

Social indicators: training, quality of life, society awareness of water resources and cover employment.

Economic indicators: saving, cover supply, process/service saving, infrastructure needs, increased crop productivity, and economic development .

Environmental indicators: change in soil composition ,cover changes in water composition (physical–chemical) and ecological quality (Alimari et al.,٢٠١٢).

To measure the above indicators, the following activities were conducted:

٣.١.٢ Socioeconomic impacts of treated grey water

٣.١.٢.١ Field Questionnaires Formulation

A field survey covered the main groups of interest for reuse of treated greywater in irrigation in north west bank. Questionnaires were designed for the target group and were distributed for the direct and indirect beneficiaries. Data were collected and analyzed using Excel and SPSS package.

٣.١.٢.٢ Questionnaire themes

The sample size of ٧١ households was selected and personally interviewed from two governorates Jenin ٣٣ and Tubas ٣٨.

The questionnaire covered baseline information on the following:

- Social information on farmer’s household.
- Irrigation quantities, quality, cost, irrigation methods.
- Level of awareness of safety reuse of greywater.
- Identification of the impact of greywater treatment unit on the environment.
- Evaluation of the total saving in freshwater use.
- Evaluation of the farming, fertilizer use ,and crop patterns.
- Conduct economic analyses to assess previous farming practices and farm greywater reuse scheme.

٣ .٢ Greywater Sampling

Field visits were carried out to determine greywater sampling, and greywater treatment unit locations in Jenin and Tubas. Six unites were chosen. sampling was conducted according to ministry of agriculture guide line.

٣. ٣ Chemical analysis of the greywater in target area

Analysis of the greywater before and after the treatment were performed acquiring several samples and analyzing the parameters. These include analysis of Cations such as: $Mg^{٢+}$, $Ca^{٢+}$, K^{+}, Na^{+}, and Anions such: $NO^{٣-}$, $PO٤^{٣-}$,Cl^{-}, $CO_{٣}^{٢-}$. Other important parameters include chemical oxygen demand (COD), biological oxygen demand (BOD), Conductivity, Total Coliforms (TC), and the Total Dissolved Solids (TDS).

٣ .٤ Soil sampling

Soil samples were collected from three plan from Tubas and Jenin village (three home gardens irrigated by treated greywater) and control sample irrigated by fresh water. sampling was conducted according to ministry of agriculture guide line. Samples were collected from two depth ٠-٣٠ cm and ٣٠-٦٠cm and placed in plastic bags for transport and storage.

٣.٤.١ Chemical analysis for the soil.

Analysis of the irrigated soil with treated greywater will be performed acquiring several soil samples and analyzing the parameters. These include analysis of Cations such as: $Mg^{٢+}$, $Ca^{٢+}$, K^{+}, Na^{+} and Anions such: $NO^{٣-}$, $PO٤^{٣-}$, Cl^{-} and $CO_{٣}^{-٢}$. Other important parameters including Total Dissolved Solids (TDS) and the biological oxygen demand were monitored.

٣.٥ Analytical Methods of treated greywater

Several analytical methods for treated greywater parameters, namely chemical, physical and microbiological were analyzed. Chemical analyzing was conducted according to An-Najah National University.

٣.٥.١ Chemical parameters

٣.٥.١.١ pH, Total Dissolved Solids (TDS) and Electrical conductivity.

pH, TDS, EC and were measured in situ by a multipurpose EC- pH meter (HACH) (Clescerl et al., ١٩٩٨).

٣.٥.١.٢ Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD)was determined by digesting water sample with potassium dichromate and concentrated sulfuric acid, and after that sample was titrated with ٠.٠٥M potassium dichromate(Clescerl et al., ١٩٩٨).

٣.٥.١.٣ Biochemical Oxygen Demand (BOD)

The air tight bottle was filled by ١٠٠ ml water and incubated at ٢٠ (C for ٥ days. After ٥ days, Biochemical dissolved oxygen reading (ppm) was measured by using the dissolved oxygen test kit (Clescerl et al., ١٩٩٨).

٣.٥.١.٤Chloride test Cl--

Titrated ١٠ ml volume sample and١٠ ml distilled water volume (blank)and ٣ drops of potassium chromate $K_٢CrO_٤$(indicator) using ٠.٠١٤١ N $AgNO_٣$(Clescerl et al., ١٩٩٨).

٣.٥.١.٥ Sulfates (SO٤-٢)

Spectrophotometer at an absorbance of ٤٢٠ nm wavelengths was used to measure sulfate from paper-filtered sample(Clescerl et al., ١٩٩٨).

٣.٥.١.٦ Total hardness

Hardness was determined by titrated sample against disodium ethylene demine tetra acetate (EDTA) to it is equivalence point by using eriochrome black T indicator. The result changes of the solution from red to blue. After titration, pH of the sample was adjusted to ١٠.٠ with ammonium buffer kit (Clescerl et al., ١٩٩٨).

٣.٦.٢.١ Greywater station in the study area

In West Bank there are many localities with a consider able population numbers and area, mainly in the northern part, have no permanent water resources and depend mainly on rainfall or water transportation from far sources to obtain their needs for domestic and agriculture purposes. For these towns and the village that also lack sewage system, the reuse of greywater at household scale became an important tool to enhance water use efficiency, which enables people to obtain additional water to be used for irrigation purposes.

٣.٦.٢.٢ Sites selections

Jenin, Tubas which are located in North West Bank, which are a major agricultural area with limited water resources. They mainly cultivated rain fed crops, such as wheat, barley and some forages. Eastern parts of these areas are considered a marginal region with limited rainfall that do not exceed ٣٠٠ mm in the good year.

٣.٦.٢.٣ Description of household greywater treatment plant used in the research area

The constructed wetland system was developed by ICARDA and adopted by NARC. The design of the treatment unit of the "wetland system" consisted of the followings:

The greywater from the house is transferred to the manhole through a PVC pipe (diameter = ٤ inches) for further gravity separation. The manhole contains two valves for maintenance and controlling overflow to cesspits, and is covered with a concrete lid (diameter ٥٠cm, depth ٥٠cm).

Gravity separation: A ١٠٠ L tank which separates greywater into three layers: solids in the bottom (if present), the upper layer of grease and oils, and a middle layer consisting of greywater. There is a filter connected to the end of the line to take the water to the next part. The other end is connected to a pierced horizontal ٣″tube. The upper end of the U-tube is connected to a ٥٠cm tube for sampling. The ٣″ U – pipe tube were used to transfer the middle layer (water) to the next part.

The third compartment is used as up flow Tuff. This part has been constructed from concrete and cinder-blocks (Dimensions W=٨٠cm, H=٨٠cm, L= ٤m). The compartment has a slight ground slope of ١٪. There is a layer of soft sand to adjust the slope and to protect internal black-plastic cover (thickness ٦٠٠ micron). An insulating sheet of polystyrene (thickness ٢cm) is placed between the walls of the compartment and the black-plastic cover. Finally, the volcanic Tuff (diameter ~٢٠ mm) was placed in the compartment.

The fourth compartment (barrel = ١٠٠ liter) is a collection and a pumping stage. This drum is placed below the ground level by a ٢٥ cm. A concrete slab is poured into the barrel to hold it in place. Holes of ٠.٥ cm are then drilled through the sides of the barrel to a height of up to ٥٠ cm. Then, a submersible pump is installed within the barrel and an electric aeration unit is installed to pump the air from the bottom of the barrel to the top (bubbling air). A drip irrigation system is connected with the setup to efficiently distribute the water to the garden trees (Houshia et al.,٢٠١٢)

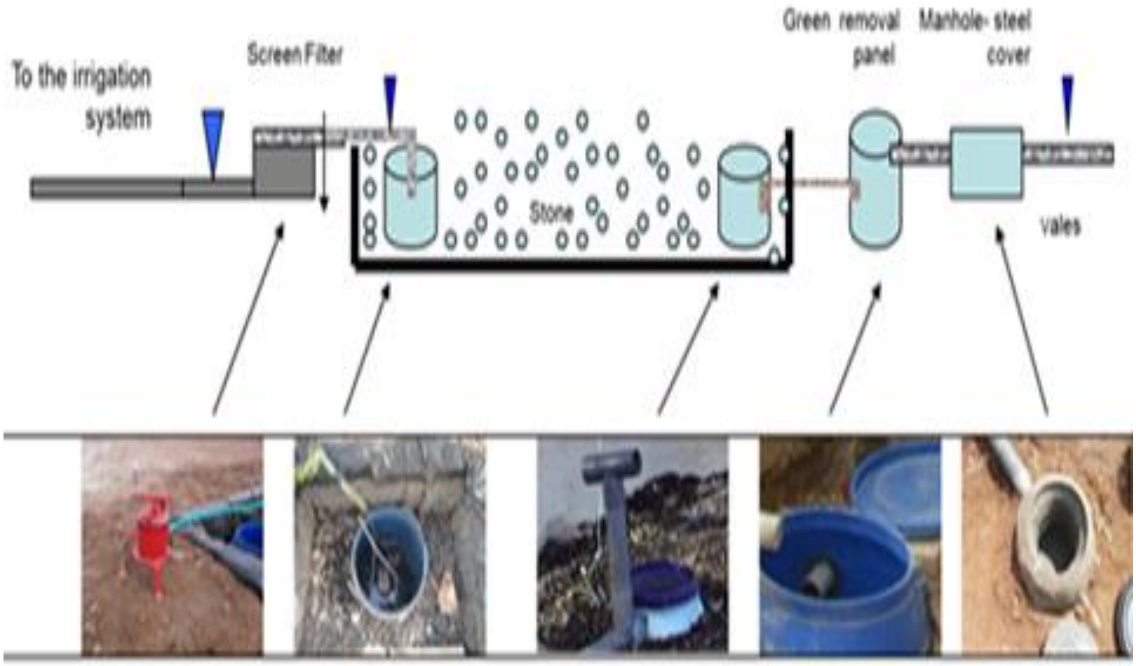


Figure (٣. ١): grey water treatment plant .

Chapter Four
Results and discussion

Research plan was fully implemented as presented in the methodology.

The result obtained as an average for all plans including short term indicator, long term indicator and socioeconomic indicator are presented and discussed below.

٤.١ Short term indicator

The short term indicator included greywater quality parameter before and after treatment during the period from June and July ٢٠١٥ (see Table ٤.١). The table show that the pH, TDS, Na^{+}, $Ca^{٢+}$, Cl^{-}, BOD, $PO_{٤}^{٢+}$ and $SO_{٤}^{٢-}$ fall with the Palestinian standard for treated wastewater (٢٠١٢). The average were ٧.٥, ١٠٢٤.٢٧, ١٢٨.٢, ٦٥.٦, ٢٢٤, ١٧٨, ٧.٦٩ and١٣٩ respectively. While $Mg^{٢+}$, $NO^{-}_{٣}$ and COD were higher than the standard. The average were ٢٨٨.٣, ٧٧.٨ and ٤٠٠.٨٣respectively (see appendix ٢)

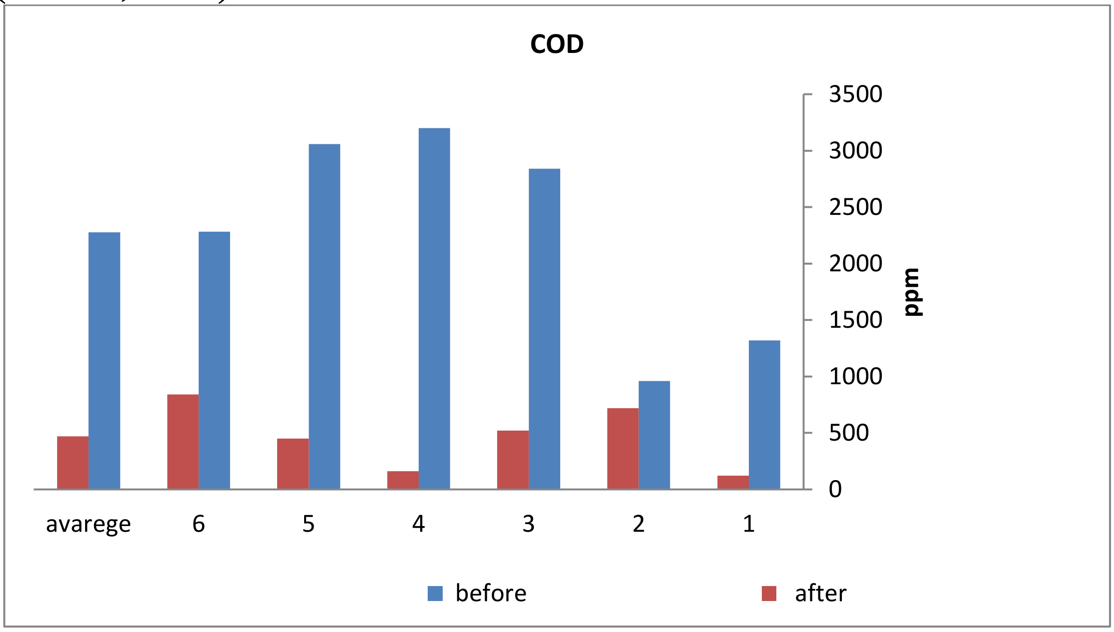
Table (٤.١): Summary of Range and Average Data Acquired from the Stations for Raw and Treated water.

Parameter	Range of raw water	Average of raw water	Range of treated water	Averageof treated water
pH	٤.٨-٦.٥	٥.٧٦	٧.٢-٧.٩	٧.٥١
EC(mmohes)	١.٠٧-٣.٥	١.٧٧	١.٢-١.٧	١.٦٠
$HCO_٣^{٢-}$ (ppm)	١٦٤.٧-٤٦٩.٥	٣٦١.٩٣	٤٦٦.٧-٧٦٤.٤	٦٠٥.٢٥
Hardness (ppm)	٣١٢.٥-٤١٢.٥	٣٢٦.٠٦	٢٨٠-٤٣٤	٣٥٣.٤٥
TDS (ppm)	٦٨٧-١٢٩٢	١٢١١.٩٢	٧٩٤-١٢٥٤	١٠٢٤.٢٧
Na^+ (ppm)	٨٨-١٣٦.٨	١١١.٥٥	١٠٦-١٥٦	١٢٨.٢
$Ca^{٢+}$ (ppm)	٣٧.٥-٩١	٦٢.٥٨	٥١-٧٨	٦٥.١٦
$Mg^{٢+}$ (ppm)	٢٢٠-٣٦٣	٢٥٨.٦٥	٢٢٩-٣٧١	٢٨٨.٢٩
Cl^- (ppm)	٢٠٤.٩-٣٩٤.٩	٣٢٦.٣٧	١٧١.٩-٣٢٩.٩	٢٢٤.٠١
K^+ (ppm)	٢٢.٧-٤١.٥	٣١.٤٧	١٧.٦-٤٧.٧	٢٨.٥٩
$NO_٣^-$ (ppm)	٦٢.٥-٨١٦	٤٥٣.٥٨	٣٣.٨-١٤٩	٧٧.٨٣
BOD (ppm)	٥٩١.٥-٧٨٨.٨	٧١٠.٤٢	١٥١-٢٤٠	١٧٨.٠٨
$PO_٤^{-٣}$	٨.٧-٢٣	١٥.٦٤	٥.٨-١٢.٥	٧.٦٩
$SO_٤^{-٢}$	١٥١-٤٥٨	٢٧٤.٥٠	٧٧.٥-٢٣٢	١٣٨.٩٩
COD	٩٦٠-٣٢٠٠	٢٢٧٧	١٢٠-٨٤٠	٤٠٠.٨٣
E-coli (cfu/١٠٠ml)	٢٦٠-٣٢٠٠	١٨٨٢.٥	١٥٧.٥-٢٨٠٠	١١٧٠.٨٣٣
T. Coliform (cfu/١٠٠ml)	١٨٣٧.٥-٢٨٠٠٠٠	١٤٥٥٠٦.	١٢٢٠-٣٤٠٠	١٠٣٤٥.٨٣

The following paragraphs are discussion of each of the indicator separately.

٤.١.١ COD

Figure (٤. ١) illustrate the values of effluent COD of the six analyzed greywater treatment plants. The minimum COD value was١٢٠ppm while the maximum was ٨٤٠ppmin the treated greywater. The minimum COD value was٩٦٠ppm while the maximum was ٣٢٠٠ppmin the raw greywater. The overall COD average was ٢٢٧٧ppm in raw greywater and ٤٠٠.٨٣ ppm in treated water. All of the measured COD values indicate that treated greywater can be used for irrigation purposes. This agreed with Al-Hamaiedeh and Bino (٢٠١٠)results were the COD in raw greywater ranged from ٩٢ to ٢٢٦٣ ppm and from ٣٦ -٧٦٣ ppm in treated greywater. The chemical oxygen demand (COD) is often high. It also typically contains indicator bacteria, including thermotolerant coliforms, hence may contain fecal pathogens. Eriksson *et al*., (٢٠٠٣) reported COD in greywater ranged from ٧٧-٢٤٠ mg/l while Carden *et al*., (٢٠٠٧) analysis of COD in greywater ranged from ١٤٧٠-٨٤٩٠ mg/l the value of COD depends largely on the amount of water used and the household cleaning products. In addition, there are differences in COD between various sources of greywater for example laundry ٧٢٥-١٨١٥ mg/l COD; and kitchen ٢٦-١٣٨٠ mg/l COD (Nolde, ١٩٩٩; Eriksson *et al*., ٢٠٠٢). Jefferson (٢٠٠٨) also identified laundry greywater as the greatest contributor to the COD of the greywater fraction. Concentration of COD in greywater is derived from household chemicals such as dishwashing and laundry detergents, food waste from the kitchen sinks, and body dirt. Although organics vary in their sorption, volatility and persistence in soil, if greywater is released to soil, high removal of organics is expected with an overall removal of ≥٩٠٪ (Weston, ١٩٩٨).



Figure(٤.١):COD values in treated greywater from the six targeted treatment plants.

٤.١.٢ BOD٥

Figure**(٤.٢)** illustrate the values of effluent BOD٥ of the six analyzed greywater treatment plants. The minimum BOD٥ value was١٥١ mg/l while the maximum was ٢٤٠mg/l for treated greywater. The minimum BOD٥ value was ٥٩١.٥ mg /l while the maximum was ٧٨٨.٥mg/l for raw greywater.

The overall BOD٥ average was in raw greywater ٧١٠ mg/l and ١٧٨mg/l for treated greywater. Typical values for BOD٥ in grey waterw as reported by Siegrist (١٩٧٧) which ranged from ٣٣-٢٩٠ mg/L, while values for an untreated domestic wastewater range from ١٠٠-٤٠٠ mg/L.Kiplagat Kotut et al., (٢٠١١) reported BOD in greywater ranged from ٤١٠-٦٢٥٠ mg/l.

This is also compared to the values obtained by Al-Hamaiedeh and Bino (٢٠١٠) where raw greywater ranged from ١١٠ to ١٢٤٠ mg/l and treated greywater ranged from ١٠ to ٤١٢ mg/l. These values of BOD٥ in this research indicated that the treated greywater can be used for unrestricted irrigation purposes.

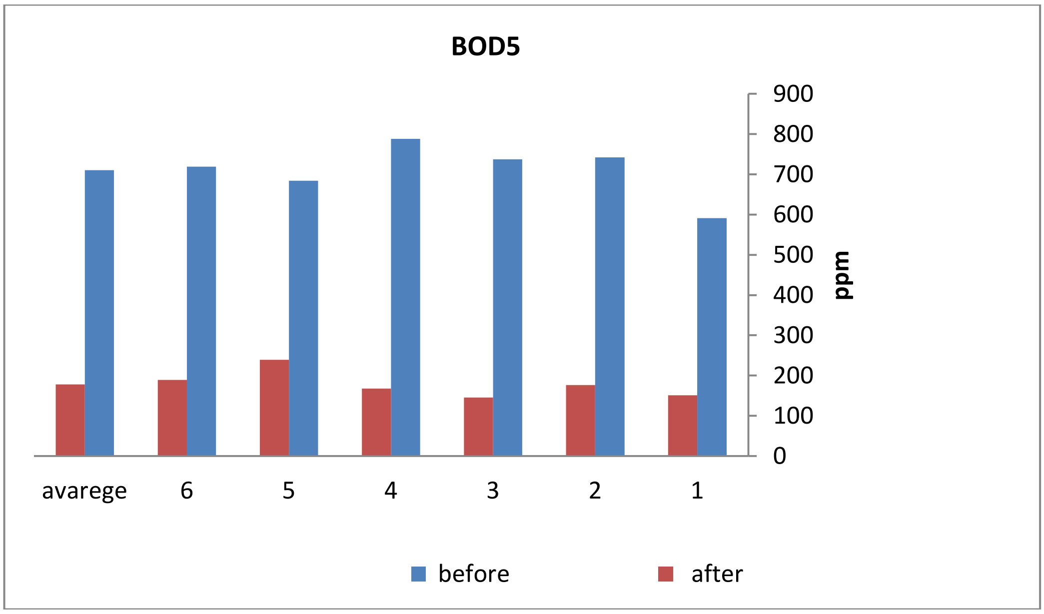


Figure (٤.٢):Values of Measured BOD٥ before and after treatment water from the six targeted treatment plants.

٤.١.٣ Phosphate ($PO_{٤}^{٣-}$)

Figure **(٤.٣)** illustrate the values of effluent $PO_{٤}$ of the six analyzed greywater treatment plants. The minimum value was٥.٨ mg/l while the maximum was ١٢.٥mg/l for treated greywater. The minimum PO٤ value was٨.٧ mg /l while the maximum was ٢٣ mg/l for raw greywater. In comparison with Eriksson et al., (٢٠٠٢) who foundthat total phosphorus ranged from ٤–١٤ mg/l this value depends on the detergents used with or without phosphate. The overall $PO٤^{٣-}$average was for raw greywater١٥.٦

mg/l and ٧.٧mg/l for treated.This data was similar to the finding of Aburahma (٢٠١٣) who reported a range from ٢-٦ mg/l with an overall value of ٣.٤ mg/l. This data fall within the Palestinian standard for treated wastewater (٢٠١٢) where it was ٣٠ mg/l for trees (appendix ٢).

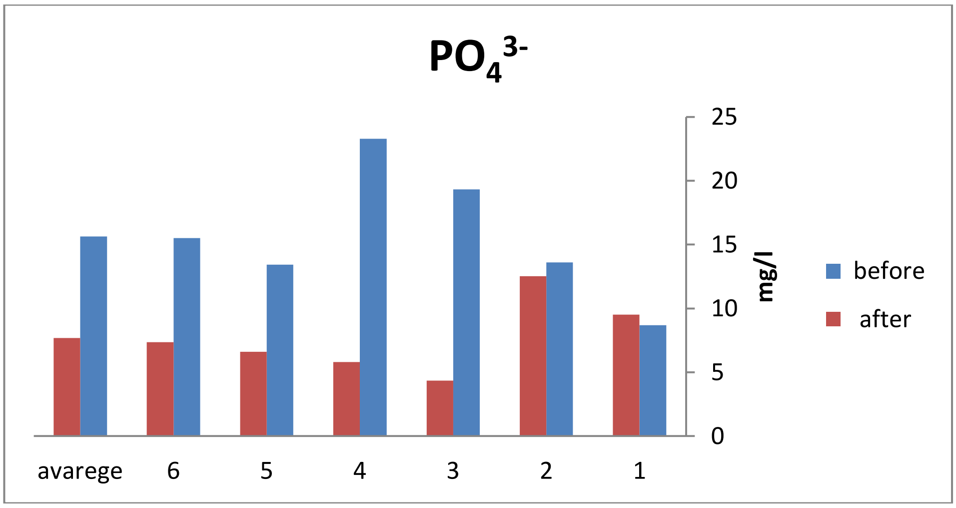


Figure (٤. ٣): Values of Measured PO٤ before and after treatment from the six targeted treatment plants.

٤.١.٤ Hardness

Figure**(٤.٤)** illustrate the values of effluent Hardness of the six analyzed greywater treatment plants. The minimum Hardnessvalue was٢٨٠mg/l while the maximum was ٤٣٤mg/l for treated greywater. The minimum Hardness value was٢٥٧ mg /l while the maximum was ٤١٢.٥ mg/l for raw greywater. The overall Hardness average was ٣٢٣mg/l for raw greywater and ٣٥٣.٥ mg/l for treated greywater. This data fall within the Palestinian standard for treated wastewater (٢٠٠٠) where it was ٤٦٠ mg/l for trees. Pangarkar et al., (٢٠١٠) reported a total hardness value of raw greywater ٣٧٤ mg/l and ١٨٧ mg/l for filtrated water.

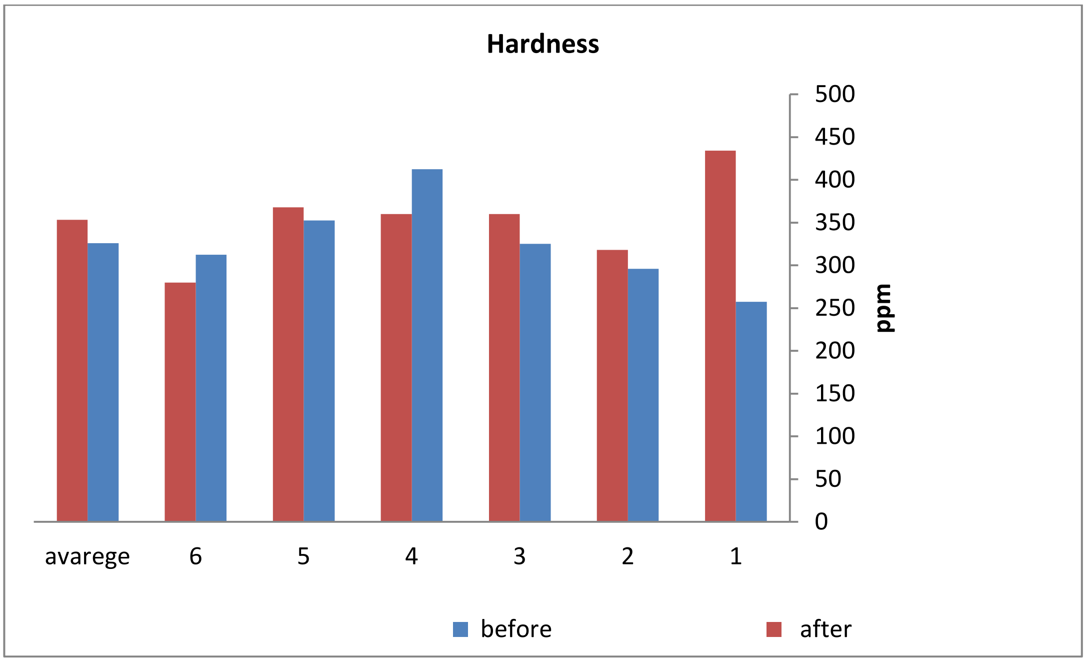


Figure (٤.٤): Values of Measured Hardness before and after treatment from the six targeted treatment plants.

٤.١.٥ $HCO_٣^-$

Figure(**٤.٥**)shows the values of effluent $HCO_٣^-$ of the six analyzed greywater treatment plants. The minimum $HCO_٣^-$ value was ٤٦٦.٧mg/l while the maximum was ٧٦٤.٥ mg/l for treated greywater. The minimum $HCO_٣^-$ value was ١٦٤.٧mg/l while the maximum was ٤٦٩.٥mg/l for raw greywater. The overall $HCO_٣^-$ average was ٣٦١.٩ mg/l for raw greywater and ٦٠٥mg/l for treated greywater.

Standard parameters values for using wastewater in irrigation according to FAO (١٩٩٢) range from less than ٩٢ for unrestricted used to greater than ٥١٩ mg/l for restricted use.

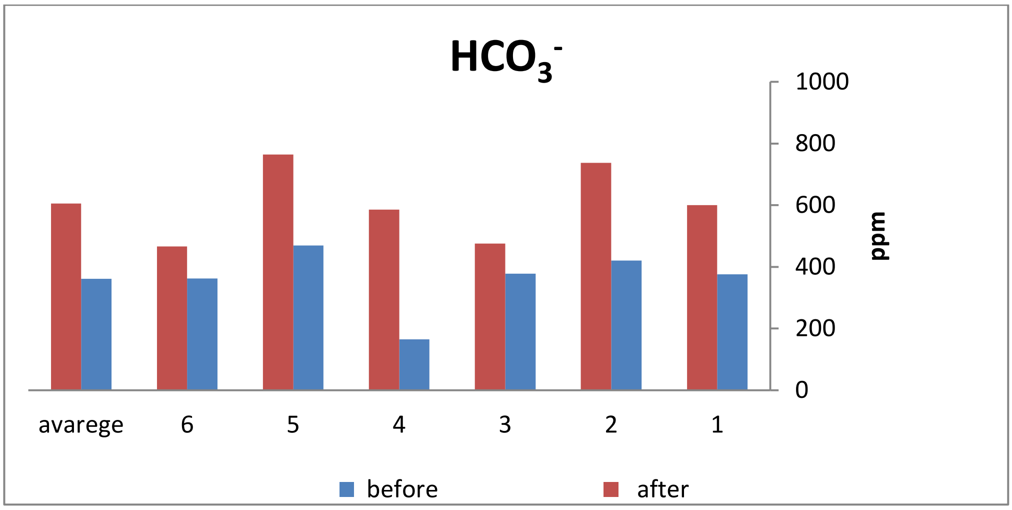


Figure (٣. ٥): Values of Measured $HCO^{-}_{٣}$ before and after treatmen from the six targeted treatment plants.

٤.١.٦ Cl^-

The analysis of Chloride effluent (figure٤.٦)shows the values of the six analyzed greywater treatment plants. The minimum Cl^- value was ١٧١.٩mg/l while the maximum was ٣٢٩.٩mg/l for treated greywater. The minimum Cl^- value was ٢٠٤.٩ mg /l while the maximum was ٣٩٤.٩mg/l for raw greywater. The overall Cl^-average was ٣٢٦.٣ mg/l for raw greywater and ٢٢٤ mg/l for treated greywater. This value of Cl^- due to precpitiation in the treatment unit after the reaction with cations Ca, Na and other .This data fall within the Palestinian standard for treated wastewater (٢٠١٢) where it was ٤٠٠-٦٠٠ mg/l for trees (appendix ٢). All samples have slight to moderate restrictions to be used in irrigation, and does not exceed the recommended limits. Aburahma (٢٠١٣) reported a minimum value of ٢٧٢ mg/l for treated greywater while the maximum was ٣٢٢.٦ mg/l with an overall average ٢٩١.٢ mg/l.

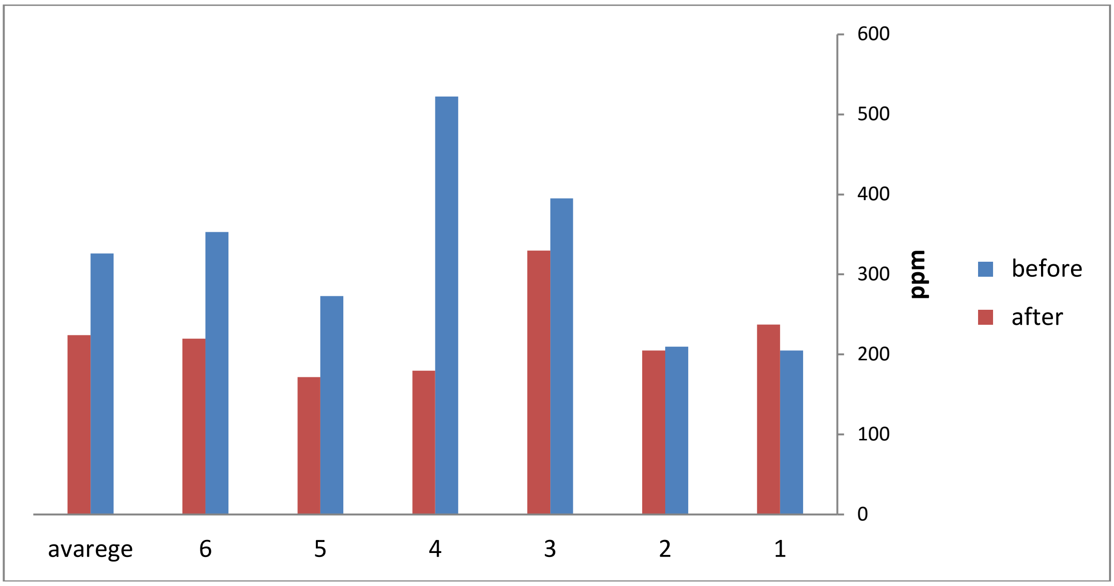
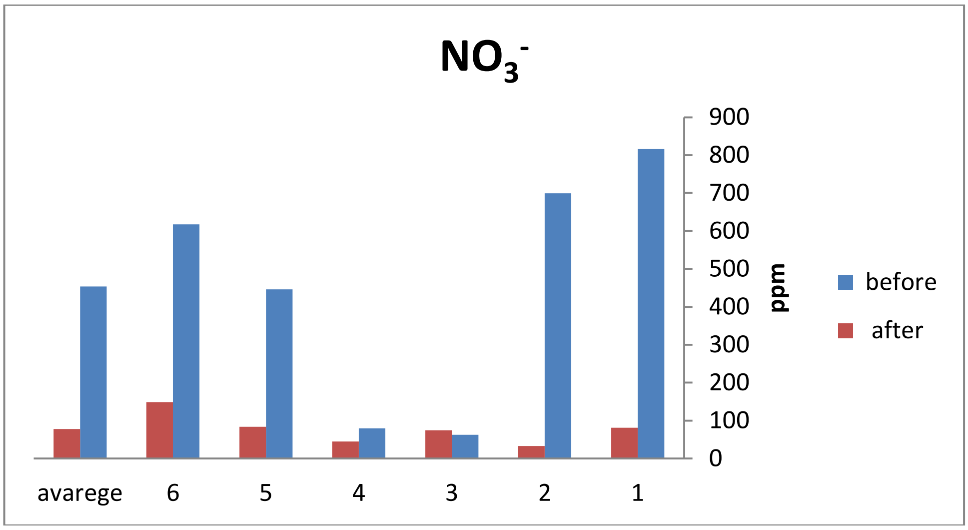


Figure (٤.٦):Values of Measured Cl^- before and after treatment from the six targeted treatment plants.

٤.١.٧ NO_3^-

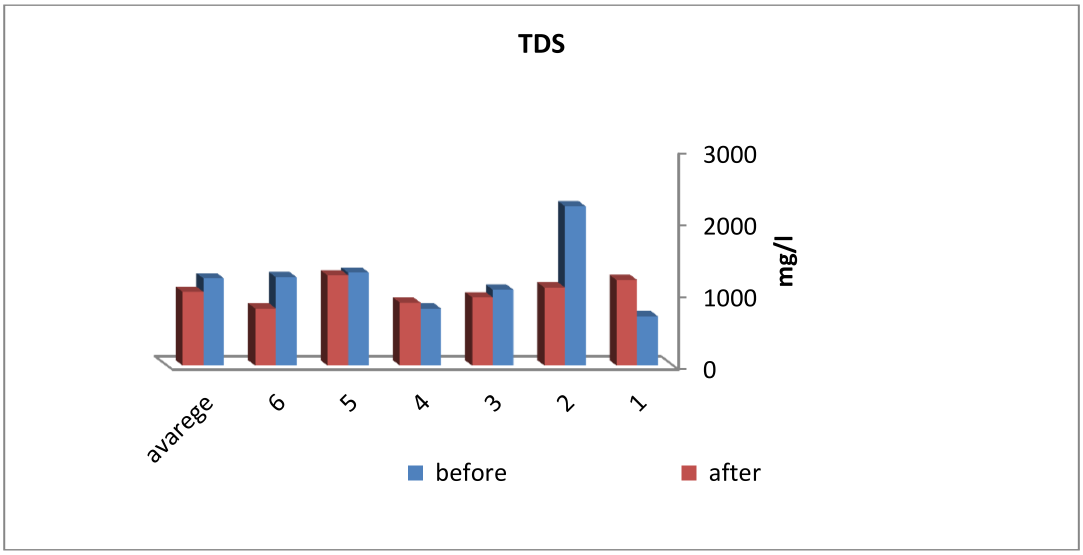
Figure(٤.٦)show the values of effluent **NO_3^-** of the six analyzed greywater treatment plants. The minimum **NO_3^-** value was ٣٣.٨mg/l while the maximum was ١٤٩mg/l for treated greywater. The minimum **NO_3^-** value was ٦٢.٥mg /l while the maximum was ٨١٦ mg/l for raw greywater. The overall **NO_3^-** average for raw greywater was ٤٥٣.٦ mg/l and ٧٧.٨ mg/l for treated greywater. Nitrate values were lower in effluent than in the raw greywater with a reduction of ٨٢.٨%. This value is higher than the Palestinian standard for treated wastewater (٢٠١٢) where it was ٥٠ mg/l for trees (appendix ٢). This value due to the denitrification resulted from bacteria . These levels of nitrate meet the FAO (١٩٨٥) standard for moderate restriction where value fall between ٩.٥- ٥١٨.٥ mg/l.



Figure(٤.٧):Values of MeasuredNO٣ before and after treatment from the six targeted treatment plants.

٤.١.٨ TDS

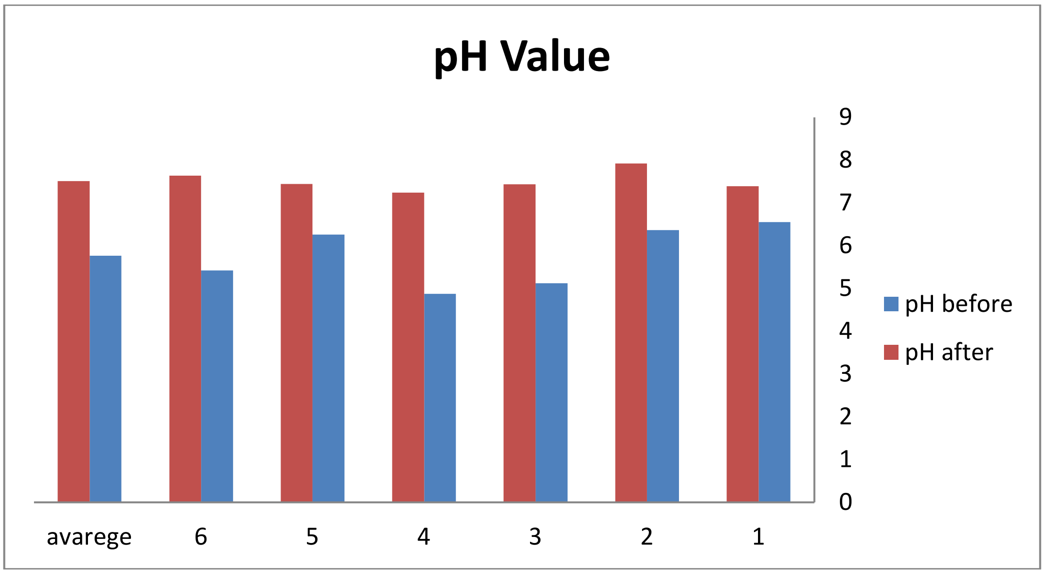
Figure(٤.٨) illustrate the values of effluent TDS of the six analyzed greywater treatment plants. The minimum TDS value was ٧٩٤ mg/l while the maximum was ١٢٥٤mg/l for treated greywater. The minimum TDS value was ٦٨٧.٤mg/l while the maximum was ١٢٩٢.٨ mg/l for raw greywater. The overall TDS average was ١٢١١.٩ mg/l for raw greywater and ١٠٢٤.٣ mg/l for treated greywater. TDS values were reduced by ١٥٪ by the treatment. This data fall within the Palestinian standard for treated wastewater (٢٠١٢) where it was ١٥٠٠ mg/l for irrigated trees(appendix ٢).



Figure(٤.٨): Values of Measured TDS before and after treatment from the six targeted treatment plants.

٤.١.٩ pH

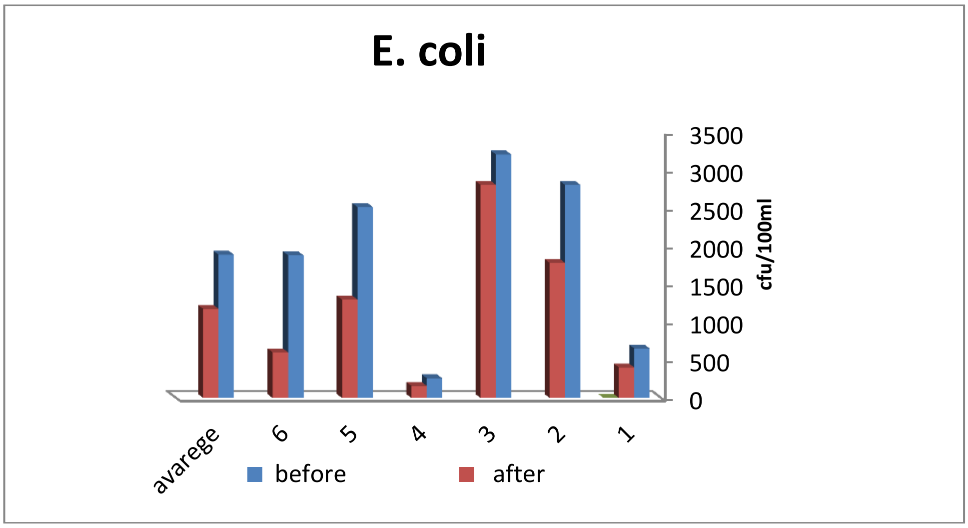
Figure(٤.٩) illustrate the values of the effluent pH of the six analyzed greywater treatment plants. The pH ranged from ٧.٢ to ٧.٩ for treated greywater while the range from ٤.٨ to ٦.٥ for raw greywater. The overall pH average was ٥.٨ for raw greywater and ٧.٥ for treatment greywater. This increase pH resulted from the degradation detergent which could release cations as P, Na^+, K^+ , in the treatment unit, addition of the effect sulfonic acid setric acid used in preparation detergent. The overall average was ٧.٣ and falls within the standard limits. The variability of pH values indicates that the constituents of greywater are not steady and changes from acid to base depend on the discharged greywater from domestic sources. The lower pH values may result from the use of water without any alkalinity adjustment, whereas the high figures indicate the presence of bleach. This data fall within the Palestinian standard for treated wastewater (٢٠١٢) where it was ٦-٩ for irrigated trees(appendix ٢).



Figure(٤.٩):Values of Measured pH before and after treatment from the six targeted treatment plants.

٤.١.١٠ E. coli

Figure **(٤.١٠)**illustrate the values of effluent E. coliof the six analyzed greywater treatment plants. The range of E.colifrom١٥٧.٥ to ٢٨٠٠ cfu/ml for treated greywater and ranged from ٢٦٠ to ٣٢٠٠for raw greywater .The overall E. coli average was ١٨٨٢.٢ cfu/١٠٠ml for raw greywater and ١١٧٠.٨ cfu/١٠٠mlfor treated greywater. E. coli is bacteria that may or may not be pathogenic, and its ubiquitous in the human intestinal tract. Generally more than ٩٠٪ of the fecal coliform are Escherichia (usually written as E. coli). This value is higher than Palestinian standard for treated wastewater (٢٠١٢) where it was ١٠٠٠ cfu/١٠٠ ml for irrigated trees (appendix ٢).When untreated greywater is stored, it will turn septic, giving rise to offensive odors and providing suitable conditions for microorganisms to multiply. E. coli multiplies between ١٠ and ١٠٠ times during the first ٢٤ to ٤٨ hours of storage. Therefore, untreated greywater must only be stored temporarily, for less than ٢٤ hours, in a surge tank.

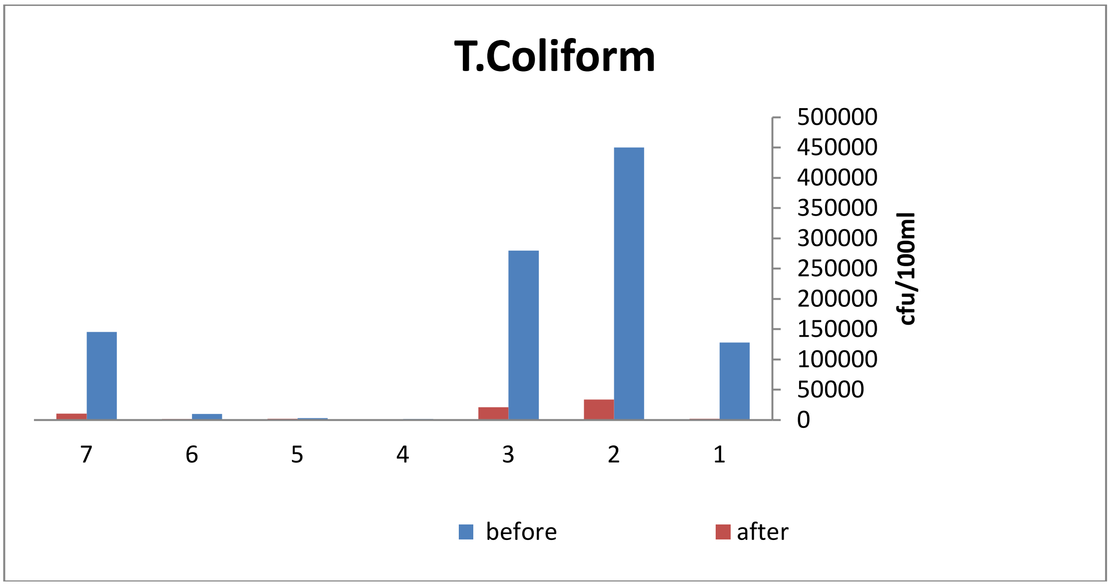


Figure(٤.١٠): Values of Measured E. coli before and after treatment from the six targeted treatment plants.

٤.١.١١ TotalColiform

Figure(**٤.١١**) illustrate the values of effluent T.Coliform of the six analyzed greywater treatment plants. The treated greywater ranged from ١٢٢٠ to ٣٤٠٠٠cfu/١٠٠ ml and the raw greywater ranged from ١٨٣٧.٥ to ٢٨٠٠٠٠cfu/١٠٠ ml. The overall E. coli average was ١٤٥٥٠٦.٣ cfu/١٠٠ ml for raw greywater and ١٠٣٤٥.٨cfu/١٠٠ ml for treated greywater. Total Coliform counts generally were high and exceeded our dilution ranges. Guideline (Dixon, A., Butler D., and Fewkes A., ١٩٩٩) for Fecal Coliforms in reclaimed water for irrigation is set at ٢٠٠ cfu/١٠٠.The total Coliform is an indicator that the fecal pollution has occurred and microbial pathogens might be present. Total and fecal coliforms, and the enterocci -

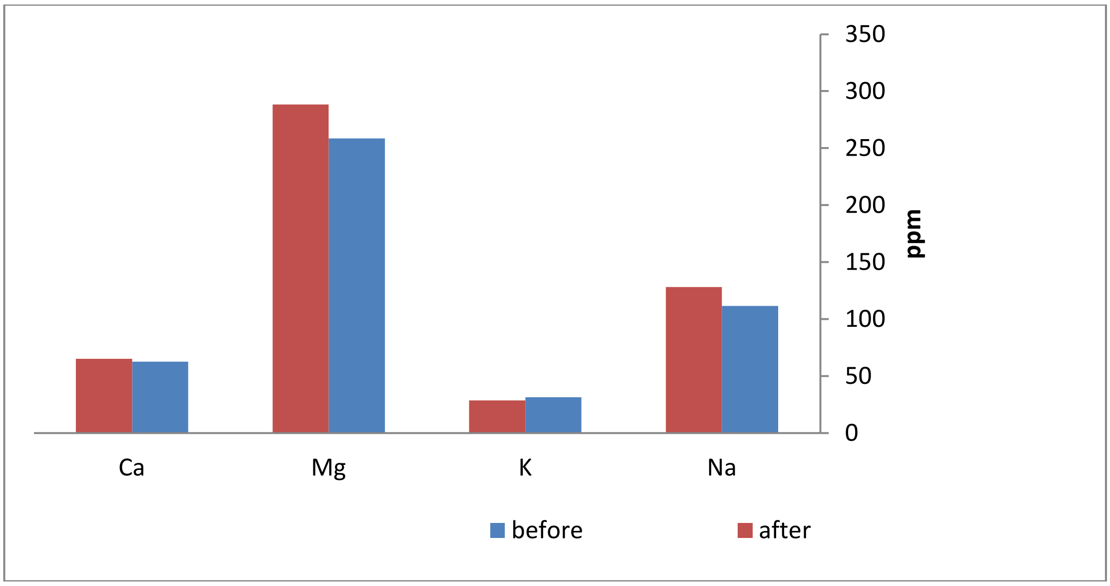
fecal streptocci are the indicator of organisms currently used in the public health area. Coliform bacteria include all aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose with gas formation. There are three groups of coliform bacteria used as standards: Total Coliforms (TC), Fecal Coliforms (FC) and Escherichia coli. Total coliforms are the broadest grouping including Escherichia, Enterobacter, Klebsiella, and Citrobacter found naturally in the soil, as well as in feces. Fecal coliforms are the next widest groups, which includes many species of bacteria commonly found in the human intestinal tract. Usually between ٦٠٪ and ٩٠٪ of total coliforms are fecal coliforms (Houshia et al.,٢٠١٢).



Figure(٤. ١١): Values of Measured Total Coliform before and after treatment from the six targeted treatment plants.

٤.١.١٢ Major cations (Mg^{2+}, Ca^{2+}, Na^{+} and K^{+})

The four major cations were analyzed during the research study are presented in Figure (٤.١٢). The presented data are within the allowable concentration for unrestricted irrigation. The concentration of some cations as $Mg^{٢+}$, $Ca^{٢+}$, Na^{+} indicated the accumulation of these cations with time.



Figure(٤.١٢): Overall average values of $Mg^{٢+}$, $Ca^{٢+}$, K^{+} and Na^{+} measured for treated greywater.

٤ .٢ Efficiency

TDS values were reduced by ١٥.٥٪ as represented in Figure ١٣. Total coliforms were lowered by ٣٣%, which was a good considering that these microbes occur in large quantities in the soil. The detected E. coli in the effluents decreased by ٣٧.٨٪ lower than in the raw greywater. This suggests a high efficiency of the stations in pathogens removing. The efficiencywas٧٠.٨% for BOD, ١٥.٥% for TDS, and ٨٧% for $NO_{٣}^{-}$ which falls within the standards approved by the Palestine Standards Institute recently and by the Palestinian Authority in ٢٠١٢ (appendix ٢) .

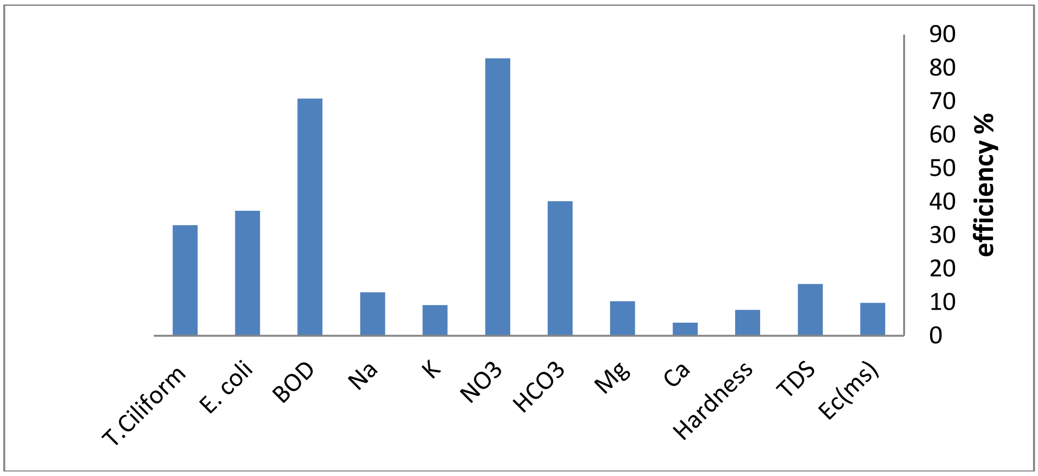


Figure (٤. ١٣): Efficiency of Treated Greywater System as Percent Removal

The results obtained from each station are presented in Tables (٤.٢ & ٤.٣) below.

Table (٤.٢): Summary for the Data Acquired from the Stations for Raw graywater (before treatment).

Station	١	٢	٣	٤	٥	٦	Average
Name	Ala' Ganam	Mahmoud Soliman	Ali Saed	Ala' Aboara	Nesreen Aborob	Mohamed Yahya	
pH	٧.١	٦.٤	٥.١	٤.٩	٦.٣	٥.٤	٥.٩
EC(mmohes)	١.١	٣. ٥	١.٧	١.٢	٢.٠٢	١.٢	١.٨
$HCO_{٣}^{٢-}$(ppm)	٣٧٦	٤٢١	٣٧٨	١٦٥	٤٧٠	٣٦٣	٣٦٢
Hardness (ppm)	٢٥٨	٢٩٦	٣٢٥	٤١٣	٣٥٣	٣١٣	٣٢٦
TDS(ppm)	٦٨٧	٢٢١٥	١٠٥٥	٧٩٢	١٢٩٣	١٢٣٠	١٢١١.٩
Na^{+} (ppm)	٨٨.١	٩٨.٩	١٢٦	١٠٧.٨	١٣٦.٨	١١١.٧	١١١. ٦
$Ca^{٢+}$(ppm)	٣٧.٥	٦٨	٩١	٤٩.٥	٦٧	٦٢.٥	٦٢.٦
$Mg^{٢+}$ (ppm)	٢٢٠.١	٢٢٨.١	٢٣٤.١	٣٦٣.٠٢	٢٨٥.٥	٢٢١	٢٥٨.٧
Cl^{-} (ppm)	٢٠٤.٩	٢٠٩.٩	٣٩٤.٩	٥٢٢.٣	٢٧٣.١	٣٥٣.١	٣٢٦.٤
K^{+} (ppm)	٤٠.٠٥	٢٢.٨	٣٥	٤١.٥	٢٤.٥	٢٥	٣١.٤٦٧
$NO_{٣}^{-}$ (ppm)	٨١٦	٦٩٩.٥	٦٢.٥	٧٩.٥	٤٤٦.٥	٦١٧.٥	٤٥٣.٦
BOD (ppm)	٥٩١.٥	٧٤٢.٥	٧٣٧	٧٨٨.٥	٦٨٤	٧١٩	٧١٠.٤٢
$PO_{٤}^{٣-}$	٨.٧	١٣.٦	١٩.٣	٢٣.٣	١٣.٤	١٥.٥	١٥.٧
$SO_{٤}$	٤٧.٩	١٠٦.٣٨	١٨.٣	٣٠.٩٤	٣١٧.٤٩	٦١.٧٧	٩٧.٢
COD	١٣٢٠	٩٦٠	٢٨٤٠	٣٢٠٠	٣٠٦٠	٢٢٨٢	٢٢٧٧
E-coli (cfu/١٠٠ml)	٤٠٠	١٧٧٥	٢٨٠٠	١٥٧.٥	١٢٩٢.٥	٦٠٠	١١٧٠.٨
T.Coliform (cfu/١٠٠ml)	١٢٨٠٠٠	٤٥٠٠٠٠	٢٨٠٠٠٠	١٨٣٧.٥	٢٦٥٠	٩٩٠٠	١٤٥٣٩٨

The above table (٤.٢) show the variation in the composition of raw water before treatment for all assessed households.

Table (٤.٣): Summary for the Data Acquired from the Stations for treated graywater (after treatment).

Station	١	٢	٣	٤	٥	٦	Average
Name	Ala' Ganam	Mahmoud Soliman	Ali Saed	Ala' Aboara	Nesreen Aborob	Mohamed Yahya	
pH	٧.٤	٧.٩	٧.٤٣	٧.٢	٧.٤٤	٧.٦	٧.٥
EC(mmohes)	١.٩	١.٦	١. ٥	١.٤	١.٩	١.٢٤	١.٦
$HCO^{٣}$(ppm)	٦٠٠.٩	٧٣٨.١	٤٧٥.٨	٥٨٥.٦	٧٦٤.٥	٤٦٦.٧	٦٠٥.٣
Hardness (ppm)	٤٣٤.٢	٣١٨.١١	٣٦٠.١	٣٦٠.٢	٣٦٧.٩	٢٨٠.١	٣٥٣.٥
TDS(ppm)	١١٨٩.١٢	١٠٨٥.١٢	٩٤٧.٥	٨٧٥.٥	١٢٥٤.١	٧٩٤.٢٤	١٠٢٤.٣
Na^{+} (ppm)	١١٦	١٤٥.٥	١٢٧.١٥	١١٨	١٥٦.٣	١٠٦.٣	١٢٨.٢
$Ca^{٢+}$(ppm)	٦٢.٥	٦٦	٧١	٦٢.٥	٧٧.٩	٥١	٦٥.٢
$Mg^{٢+}$ (ppm)	٣٧١.٧	٢٥٢.١	٢٨٩.١	٢٩٧.٧	٢٩٠	٢٢٩.١	٢٨٨.٣
Cl^{-} (ppm)	٢٣٧.٤	٢٠٤.٩	٣٢٩.٩	١٧٩.٩	١٧١.٩	٢١٩.٩	٢٢٤.٠١
K^{+} (ppm)	٤٧.٧٥	٣١.٥٥	٢٨.٣٥	١٧.٧	١٩.١٢	٢٧.١	٢٨. ٦
$NO_{٣}^{-}$ (ppm)	٨١.٥	٣٣.٢٥	٧٤.٥	٤٥.٢٥	٨٣.٤٥	١٤٩	٧٧.٨٣
BOD (ppm)	١٥١	١٧٦	١٤٥.٥	١٦٧.٥	٢٣٩.٥	١٨٩	١٧٨.٠٨
$PO_{٤}^{٣-}$	٩.٥٣	١٢.٥٣	٤.٣٥	٥.٨	٦.٦	٧.٣٥	٧.٦٩١٧
$SO_{٤}$	٤٧.٩٨٥	١٠٦.٣٨	١٨.٣١٥	٣٠.٩٤	٣١٧.٤٩	٦١.٧٧	٦١.٧٧
COD	١٢٠	٧٢٠	٥٢٠	١٦٠	١٢٤٥	٨٤٠	٦٠٠.٨
E-coli (cfu/١٠٠ml)	٤٠٠	١٧٧٥	٢٨٠٠	١٥٧.٥	١٢٩٢.٥	٦٠٠	١١٧٠.٨
T.Coliform (cfu/١٠٠ml)	١٩٠٠	٣٤٠٠٠	٢١٠٠٠	١٢٢٠	٢٢٥٠	١٦٧٥	١٠٣٤١

The above table (٤.٣) show the variation in the composition of treated graywater for all assessed households.

٤.٣.١ Long term indicator

The long term indicator includes greywater treatment result in ٢٠١١ carried out by NARC compared with the greywater treatment results in this study ٢٠١٥ and the impact of irrigation with treated greywater on chemical properties of the soil.

During ٢٠١٥, the efficiency of total coliform was ٣٣.٣٪ compared to٨٧ %in ٢٠١١. The decrease was ٥٣.٣%. In ٢٠١٥, the efficiency of E .coli was

٣٧.٣٪ compared to ٥٥.٣ %in ٢٠١١. The decrease was ١٨٪. The efficiency of BOD was ٧٠.٨ in ٢٠١٥ compared to ٧٥.٨ % in ٢٠١١. The decrease was ٥٪. The efficiency of EC was ٩.٨ % in ٢٠١٥ compared to ٢٧.٣ % in ٢٠١١. The decrease was ١٧.٥٪. The TDS decrease ١٦.٣ % (Figure ٤.١٣). The important parameters as BOD, TDS, EC, and E .coli showed a decrease in the efficiency of the stations by the time, but it remains within the accepted Palestinian standards.

It was noted that with time the accumulation of some salts such as $Ca^{٢+}$, $HCO_٣^-$, $NO_٣^-$ exposed a risk of soil sanalization when using this water for irrigation especially if the soil already has high levels of salinity.

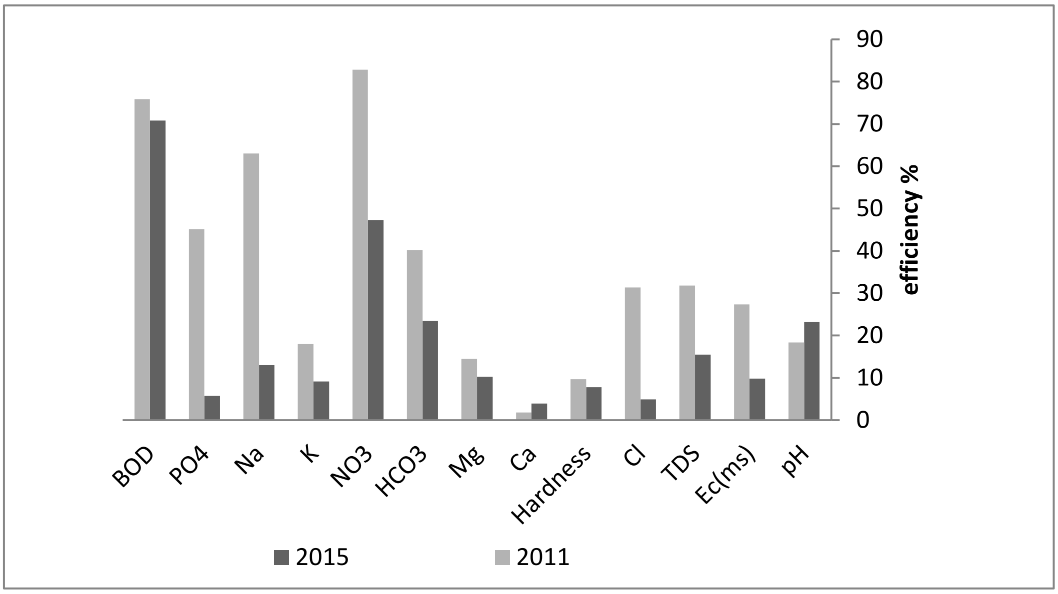


Figure (٤.١٤): The efficiency % of the plant during ٢٠١١ and ٢٠١٥.

٤.٣.٢ The impact of irrigation with treated greywater on chemical properties of the soil

The impact of treated greywater irrigation on soil was assessed by testing three soil samples irrigated by treated greywater(table٤.٥).

Table (٤.٤): Soil extract analysis results

	Soil irrigated with treated greywater						Control
Parameter	Unit	Unit A	Unit B	Unit C	Average	Sd	(Soil irrigated with fresh water)
PH		٦.٧٥	٦.٦٤	٦.٦٢	٦.٦٧	٠.٠٧	٧.٣٧
Ec	Ms	٤.٢	١.٢٥	٢.٥	٢.٦٥	١.٤٨	٠.٨
Cu	ppm	٠.٣٩	٠.٥٢	٠.٤٣	٠.٤٥	٠.٠٧	٠.٢١
Mn	ppm	٤.٥٦	٥.٨٤	٥.١	٥.١٧	٠.٦٤	٢.٢٤
Zn	ppm	٣.٦٦	٣.٠٧	٣.٢١	٣.٣١	٠.٣١	١.٦٩
Cr	ppm	٠.٦١	٠.٧٧	٠.٧	٠.٦٩	٠.٠٨	٠.٣١
$N\text{-}NO_٣^-$	ppm	٢.٧٢	٢.٨١	٢.٥	٢.٦٨	٠.١٦	١.١٧
$PO_٤$	ppm	٢٦.١	٢٥.٣	٢٥.٦	٢٥.٦٧	٠.٤٠	١٦.٦٢
$K_٢O$	ppm	١٢.٥	١٣	١٢.٦	١٢.٧	٠.٢٧	٢.٣٤
Na	ppm	٧.٥	٦.٨	٧.٢	٧.١٧	٠.٣٥	٢.١٥
Ca	ppm	١٤٥	١٨٠	١٥٥	١٦٠	١٨.٠٣	٨٣
Mg	ppm	٧٣	٧٧.٨	٧٤.٦	٧٥.١٣	٢.٤٤	٤١.٣
CL	ppm	٤٦٥	٢١٦	٢٩٠	٣٢٣.٦٧	١٢٧.٨	١٨١
SAR	ppm	١.٠٢	٠.٨	١.١٣	٠.٩٩	٠.١٦	٠.٢٩

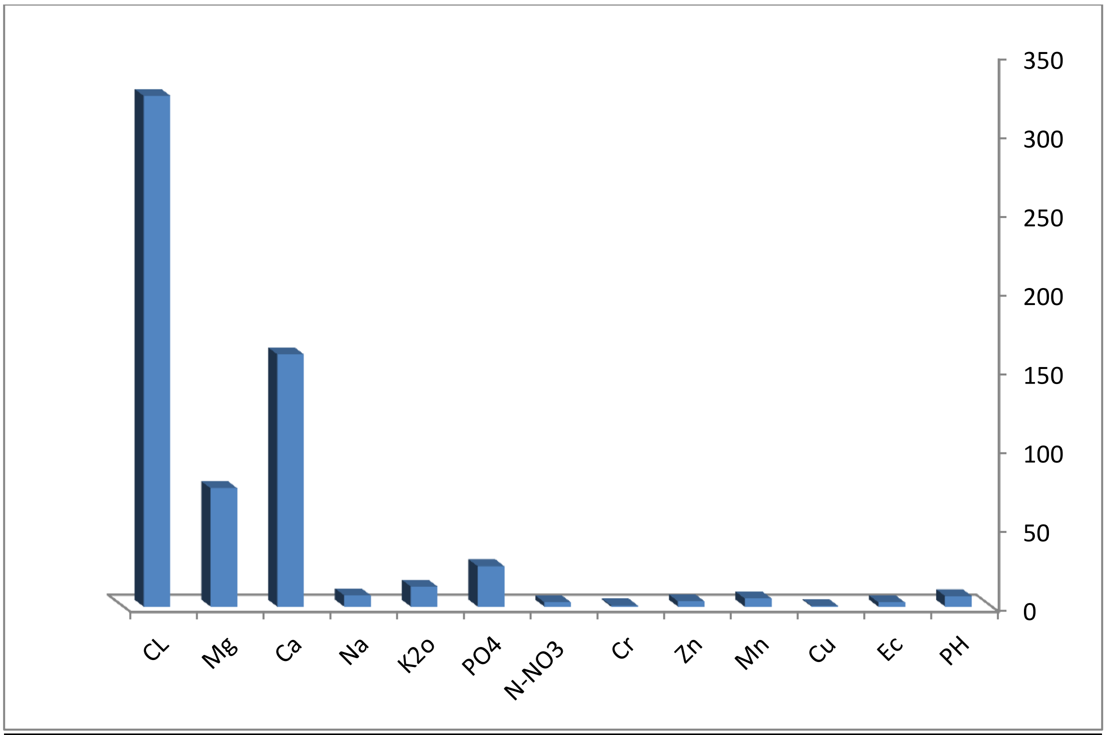


Figure (٤.١٥): Impact of irrigation with treated greywater on chemical properties of the soil

٤.٣.٢.١ pH values

The variation of pH values, seems to be constant and it is remained in the average ٦.٧٦.McIlwaine and Redwood (٢٠١٠) reported value for pH of soil not subject to greywater irrigation ranged from ٧.٧ to ٧.٩. In comparison to previous research soil sample from different depth where the pH values of ٧.٥, ٧.١, and ٦.٩ for the ٣٠-, ٦٠-, and ٩٠-cm soil depths, respectively. (Veneman and Stewart ٢٠٠٢).

٤.٣.٢.٢ Electrical conductivity (EC)

The electrical conductivity (EC) of the soil correlated with soil properties and affect crop productivity, cation exchange capacity (CEC), drainage conditions, organic matter level and salinity. The average EC ٢.٦٥ for soil irrigated with greywater while the average EC ٠.٨ for soil irrigated with freshwater.

Mohammad and Mazahreh (٢٠٠٣) found that wastewater irrigation increased the level of total salinity due to the wastewater salt content.. greywater projects undertaken in neighboring Jordan have found that there were slight increases in soil salinity in the years after greywater systems were introduced (Murad & Ayes,٢٠١٠). According to the WHO guidelines, salinity problems can occur when soil conductivity is greater than ٣ m/Sm (deciSiemens per meter); in the Jordanian case, salinity levels rose from ٠.٣٤-٠.٩٦ m/Sm before greywater use to ١.١-١.٨٢ m/Sm afterward (WHO ٢٠٠٦; Murad, AlBeiruti& Ayes ٢٠١٠). While this increase is worrisome, it remains well below the levels at which salinity problems can occur.

٤.٣.٢.٣ Heavy metals (Zn, Cu,Cr&Mn)

The average concentrations of Zn, Cu, Cr and Mn were ٣.٣,٠.٤٤,٠.٦٩ and ٥.١٦ respectively in soils receiving treated greywater were not significantly higher. The results also do not show any relationship between long time application of greywater and heavy metals accumulations in the soil. Mohammad and Mazahreh(٢٠٠٣) reported that soil Zn and Cu were not significantly affected by wastewater irrigation. Zhang et al,(٢٠٠٧) conduct a research in China and reported soil salinity increase due to irrigation with treated wastewater, but remained within the acceptable standards. Hamidiah (٢٠١٠) found the irrigation with treated greywater for about five years did not show accumulation of heavy metals in the soil, which might be due to leaching of soil by rain and tap water.

٤.٤ Socioeconomic indicator

The field survey results are listed below by governorates. The questionnaire covered many topics including general information, infrastructure, crops, extension, gender, credits and water. Table (٤.٥) shows that a sample of ٧١ households was selected and personally interviewed from two governorates Jenin(٣٣) and Tubas (٣٨).

Table(٤.٥): Sample distribution by governorate.

Governorate	Percent	Village	Percent
Jenin	٤٦.٥	Jalbon	١٦.٩

		Der Abod	١٥.٥
		Faqu'a	١٤.١
Tubas	٥٣.٥	Tayaseer	٢٥.٤
		Aqaba	٢٨.٢
Total	١٠٠.٠	Total	١٠٠.٠

The average number of family members is ٦.٤ and the average of the income is ٢١٩٤ NIS. The average number of males is ٣.٣ and the average number of females is three. The basic education has ٦٣.٤ % of the sample and ٢٩.٦ % has a higher education (Table ٤.٦).

Table(٤.٦). Personal information for the studied communities.

Item	**unit**
Number of families	٧١
The average number of family members	٦.٣٨
Average income	٢١٩٤
The average number of males in the family	٣.٣
The average number of females in the family	٣
The average number of households owning garden	١.٣٨
Rate area of the garden	٢٥٧.٦
No of family own cesspit	٦٢
No of family own GWTP	٩
Who possess electricity network ratio	١٠٠٪
Who owns the water rate system	١٠٠٪
Who possess a sewage network rate	٠
The proportion of those with basic education	٦٣.٤
The proportion of those with a university education	٢٩.٦

٤.٤.١ Extension and environmental awareness

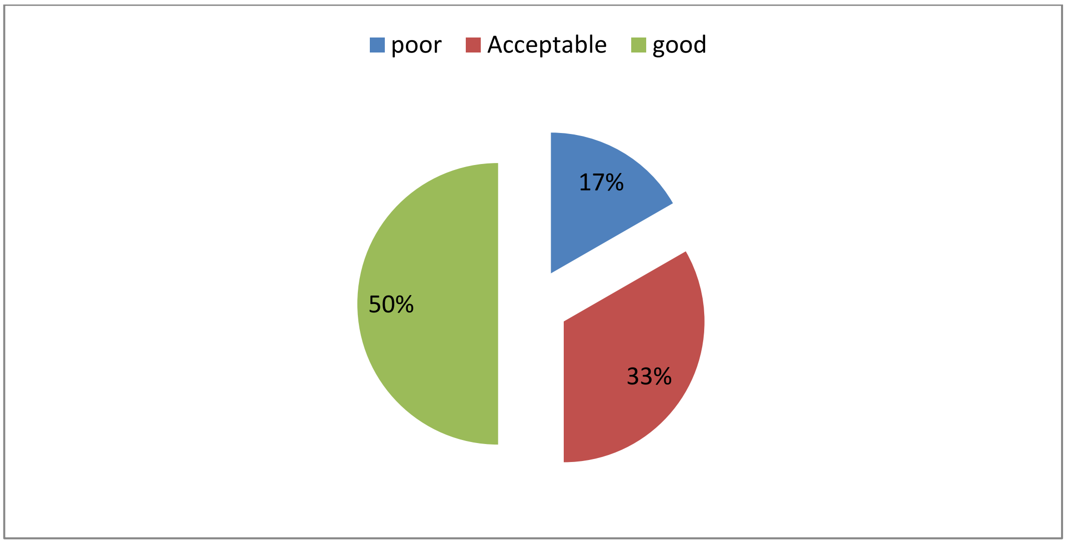
In total, ١٥.٥ % of the families had environmental training course. However, the acquired knowledge on greywater was ١٦.٧٪ and the acceptance to purchase crops irrigated with greywater by the people was ٥٩ % (Table٤.٧).

Table(٤.٧).Percent of families have environmental training course, acquired knowledge and acceptance to buy crops irrigated with greywater

Item	Percent
Percent of families have environmental training course	١٥.٥
Acquired knowledge on greywater	١٦.٧
Acceptance to pay crops irrigated with greywater	٥٩

٤.٤.٢ Water consumption

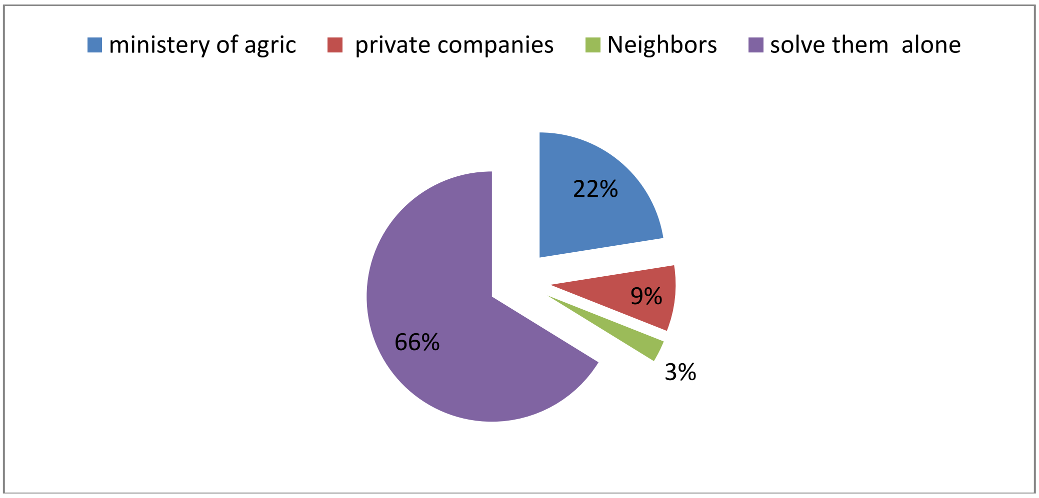
The total ١٩ M٣ of freshwater per month is the consumption of householders. The results of the analysis indicated that ١٥.٥٪ of the surveyed farmers were not satisfied with the services of extension, against ٣٣٪ of them stated that the level of these services is acceptable, and ٥٠% of them rated extension services as good (Figure ٤.١٦).



Figure(٤.١٦): Level for agricultural service

٤.٤.٣ Role of extension agents

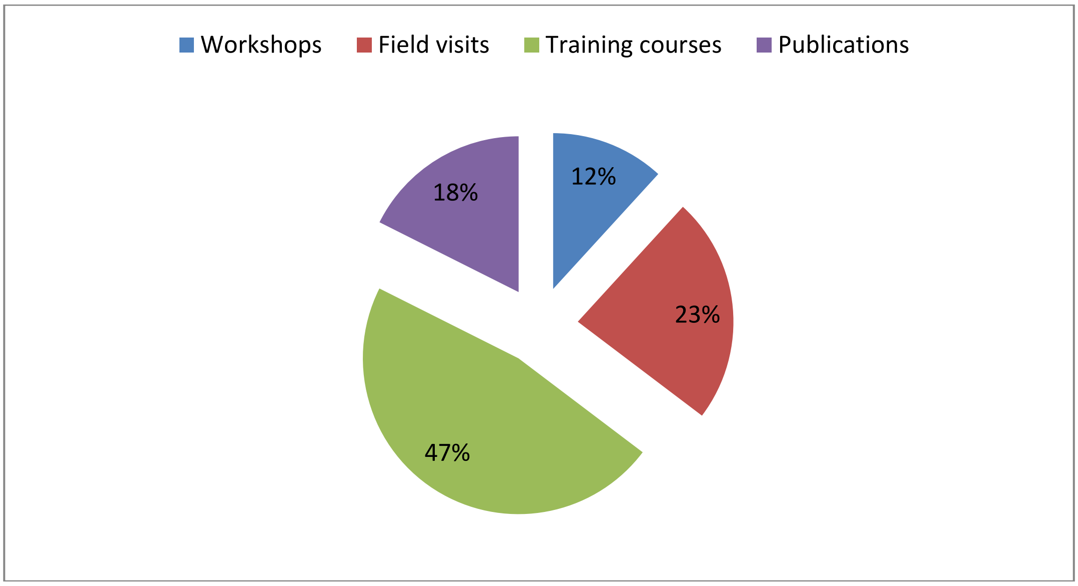
When farmers face a serious agricultural problem, ٦٦٪ of them are trying to solve it by themselves, and only ٢٢٪ of them refer to extension agents (Figure ٤.١٧).



Figure(٤.١٧): Farmers oriented when a problem occurs

٤.٤.٤ Information on treated greywater

About ١٦.٧٪ of the individual received information on the indicative greywater and ٨٣.٣٪ had no information. About ٤٧٪ of the nature of this information were a training course (Figure ٤.١٨).



Figure(٤.١٨): The nature of the information indicative of greywater

Figure (٤.١٩) illustrated that ٦٠٪ of individuals do not have greywater information and ١٨.٥٪ have little information. This reflects the lack of awareness and guidance campaigns.

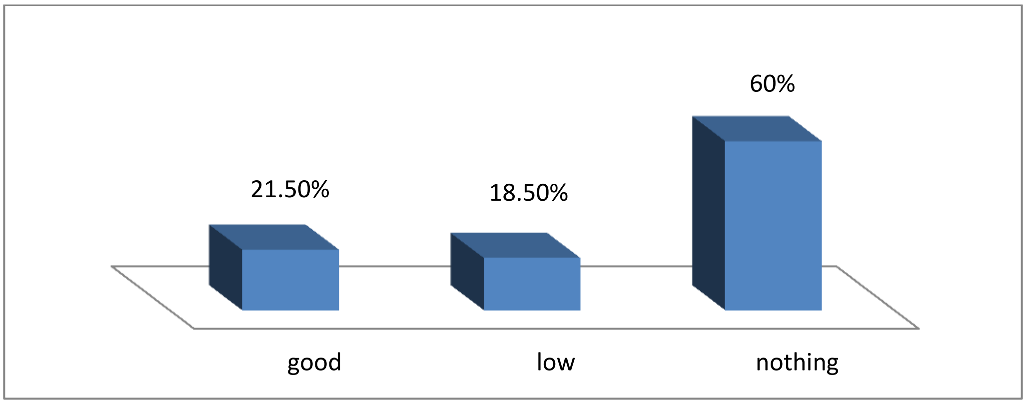


Figure (٤.١٩): The information of the families on the use of treated greywater in agriculture.

٤.٤.٥ knowledge on the use of greywater

About ٦١% of the farmers indicated that they have no knowledge on the use of greywater. The source of the information on greywater treatment from the private sector was ١٥.٢٪ and ١٢٪ from neighbors (Figure ٤.٢٠).

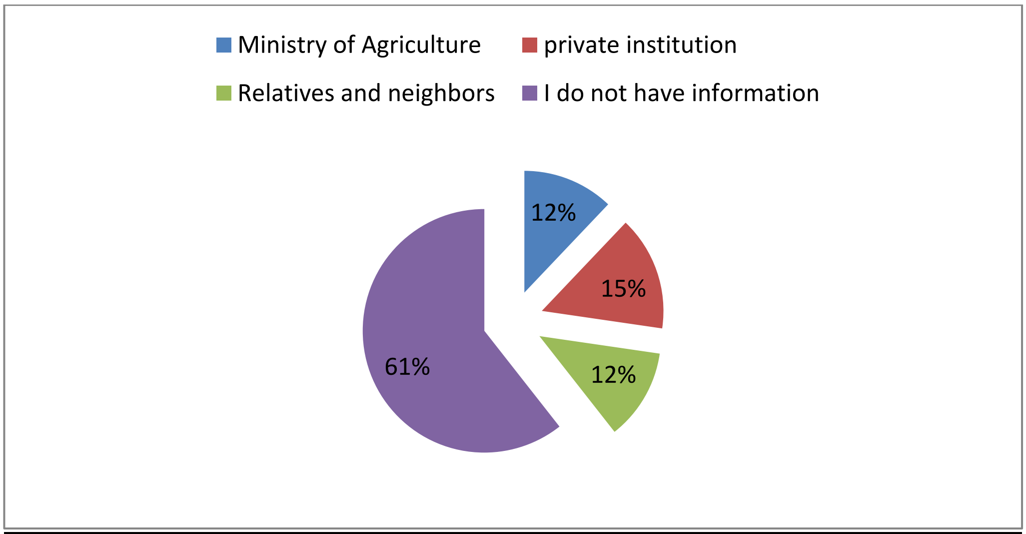
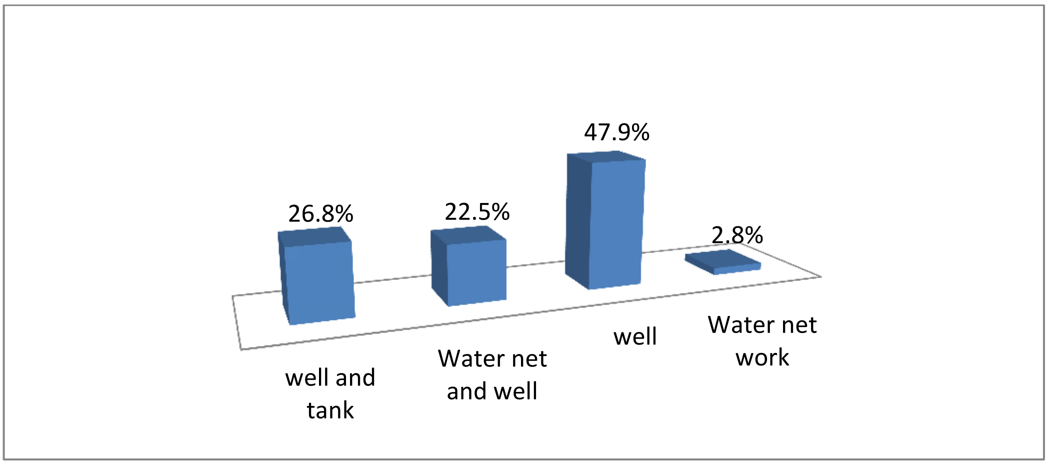


Figure (٤.٢٠): Source of information about the use of greywater

٤.٤.٦ Source of water for irrigation

About ٤٨٪ of the farmers get irrigation water from wells, ٢٧% from tanks and ٢.٨ from the networks and this constitutes a major problem facing farmers (Figure ٤.٢١).

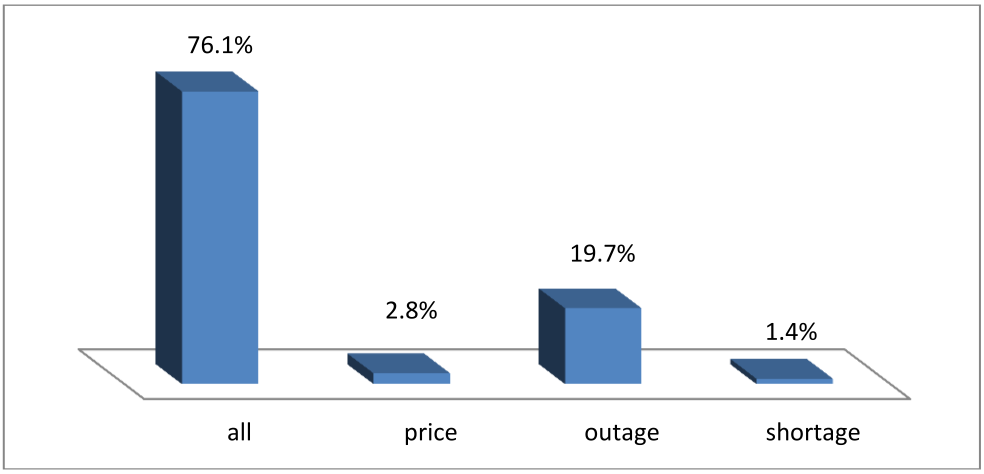


Figure(٤.٢١): Source of water used for garden irrigation

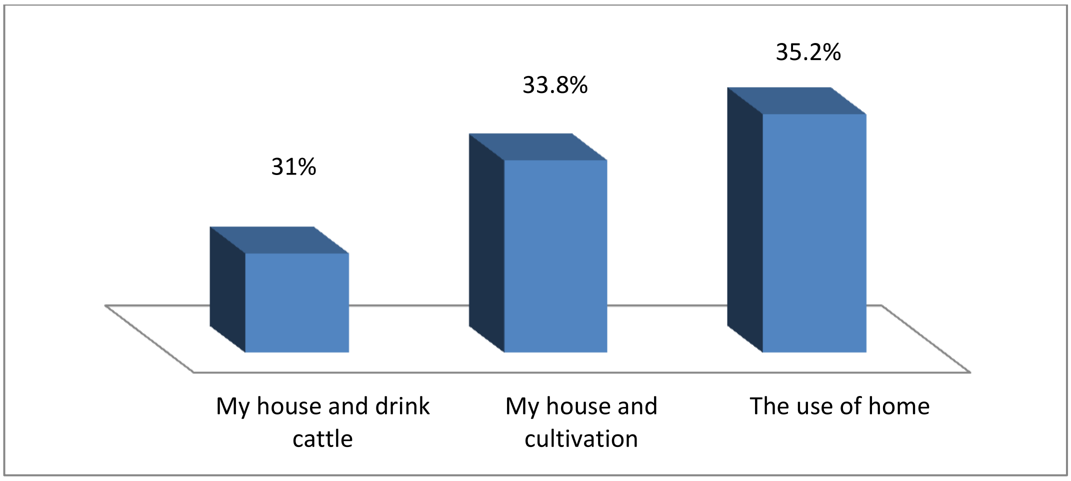
٤.٤.٧ Water services

Water services analysis shows that nearly ٧٦٪ of the respondents face a water shortage and the same percent reported that water prices being a major constraint they have to deal with (Figure ٤.٢٢).Moreover, ٣٥ % of respondents stated that they use freshwater for washing and ٣٤٪ for irrigation gardens (Figure ٤.٢٣).

Figure (٤.٢٢) shows ٣٥.٢٪ consumed water for just domestic use and ٣٣.٨٪ of families use water for agriculture and domestic use.



Figure(٤.٢٢): Major water problems



Figure(٤.٢٣): The most important uses of water

Table (٤.٨). Cesspits average discharge number per year, cost and acceptance to construct GWTP

Item	Percent/ cost
Solid cesspit	٤٦٪
Average discharge number per year	٦.٧
Average cost per each time	٩٥nis
Acceptance to construct GWTP	٦٠٪

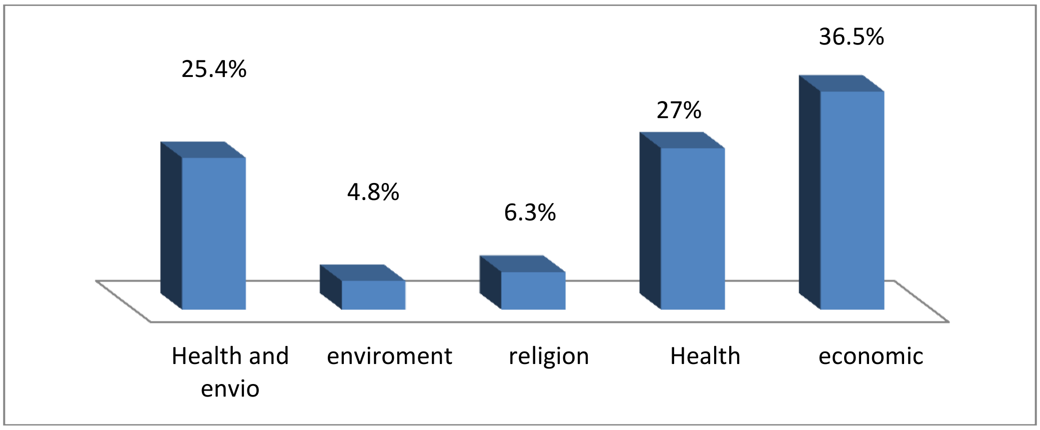
Table (٤.٨) shows the average number of seepage times is ٤.٦ and the average cost is ٩٥ NIS per each time. This reflects the high cost of the seepage. Moreover, ٣٣٪ of treatment unit owners stated that the units need regular maintenance. About ٧١ % of unit's owners stated that the units increase crop production in the home garden. In addition, ٨٩ % of them indicated the decrease in units efficiency by the time and this with the agreement with chemical analysis.

٤.٤.٨ General information of GWTP unit

The treatment units (constructed wetland) which are distributed in the rural communities have been constructed over the last five years by NARC in collaboration with ICARDA. The finding showed that ٣٣٪of the total constructed treatment units were not operated any more due to many reasons including strong bad odor and its impacts on the owner and neighbors. These results agreed with the results of Thaher and Mahmoud (٢٠١٢).

The treatment units require the availability of enough space area surrounding the home. The average area of garden is ٥٣١ m٢. On average ٩٨.٣ % of houses have a rain water harvesting system. The yield and food security were improved by ٧٧.٨ %. Sandec (٢٠٠٦) pointed out that reuse of treated greywater in irrigation can significantly contribute to reducing water bills and increasing food security.

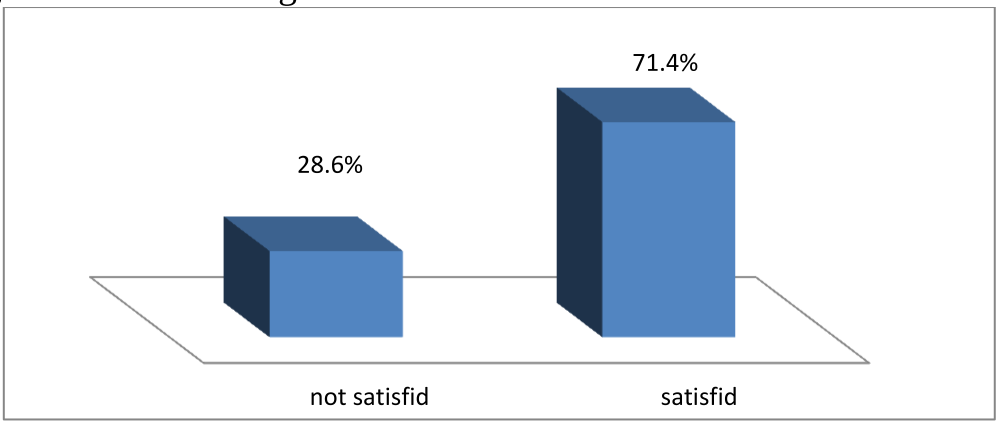
The economic factor (٣٧٪) was limiting factor for dissemination of the treatment units among the communities (Figure ٤.٢٤).



Figure(٤.٢٤): Limiting factor for dissemination of the treatment units among the communities

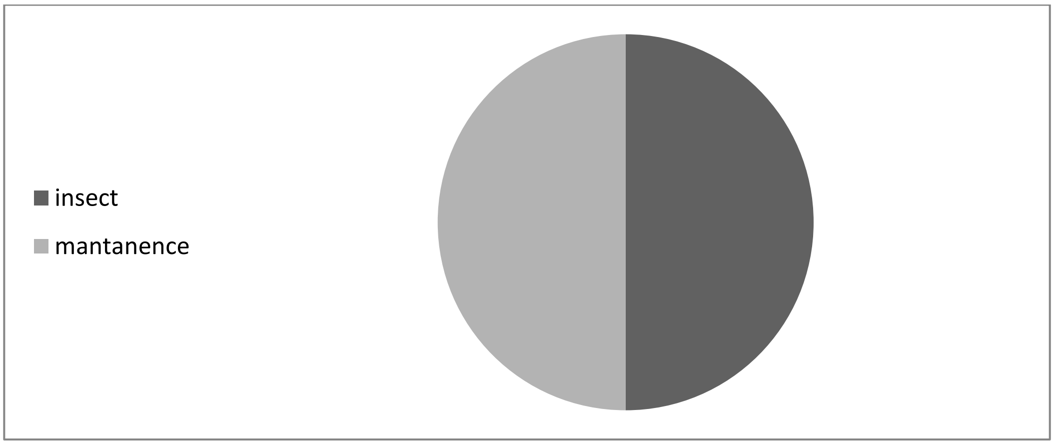
People's satisfaction with the applied GWTPs was promising, as the majority of GWTPs beneficiaries showed ٧١.٤٪ are satisfied with the treatment unit (Figure ٤.٢٥).

This results agreed with Khatun et al,(٢٠١١) founding where many people still willing to accept greywater and adapt it to secure their water need for irrigation due to shortage of water resources in the studied area.



Figure(٤.٢٥): Peoples satisfaction with the applied GWTP

Other reasons for the not satisfaction of the GWTP beneficiaries was due to maintenance and insect with ٥٠ % of the total beneficiaries (Figure ٤.٢٦).



Figure(٤.٢٦): The important problem of GWTP

٤.٤.٩ Wastewater Systems “Cesspits” for the households who have no treatment units at their houses.

The findings showed ٨٣٪ household interviewers have no idea about greywater treatment systems. The majority of households ٦٠٪ preferred the use GWTPs. About ٨٧.٣٪ of the households used cesspits as the main applied system for wastewater disposal.

About ١٢٪of the cesspits owners did not ever discharge the wastewater from cesspits since construction, and ٨٨٪ discharge the cesspits each month، this explains the pollution of the groundwater in which wastewater percolate directly into the ground layers cause a direct pollution to groundwater, soil contamination, and the negative effects on agriculture (PWA, ٢٠١٠).

About ٧٠٪ of cesspit’s owners were not satisfied due to many reasons such as financial burden on householders of continuous cesspits emptying, environment pollution and leakage of wastewater to the neighboring cistern, health concerns and odor emission, insects infestation, high capital cost for cesspit construction and system’s blockage (figure ٤.٢٧).

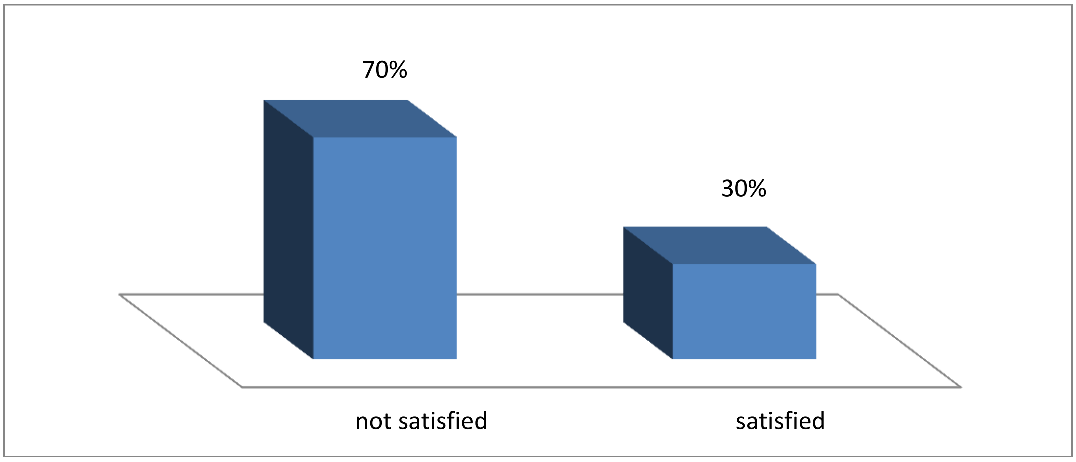


Figure (٤.٢٧): Level of cesspit’s owners satisfied

The average times of cesspits pools discharge were ٦.٧ per year for the households who don't won treatment units and ٤.٢ per year for the households who won treatment units. The average cost for each time of the discharge is ٩٠ NIS. The cost was decreased ٣٧٪ by the use of treatment units.

٤.٤.١٠ Relations between dependent factor and qualitative factors (independent):

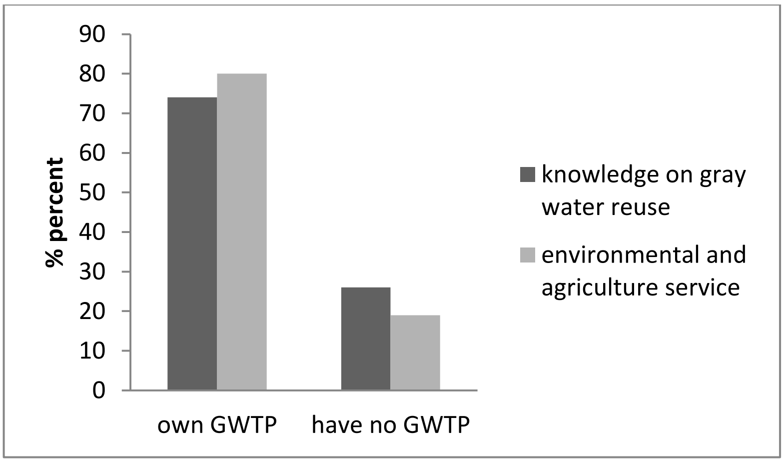
The relations between the people who use GWTPs for garden irrigation(dependent factor) compared to the qualitative independent factors are indicated in table (٤.٩). The independent factors were: family size, knowledge of greywater treatment use for irrigation, education level, environmental and agriculture service and acceptance to buy crops irrigated with treated greywater.

Table(٤.٩): Chi square for use GWTPs for garden irrigation qualitative independent factors.

Item	Sig.	Value	Df	Status
Family size	٨.٢	٥.٢٤٦	١١	Not significant
Knowledge of greywater treatment use for irrigation	.٠٠٠	٢٩.٠٦	١	Significant
Education level	.٥٩٨	١.٨٧٧	٣	Not significant
Environmental and agriculture service	.٠٠	٢١.٨٢٣	١	Significant
Acceptance to buy crops irrigated with treated greywater	.٢٠	٤.٦٤٤	٣	Not significant

The rates of increased knowledge on greywater reuse, environment and agriculture service was significant for household who own GWTP (P < ٠.٠٥).Family size, Education level and acceptance to buy crops irrigated with treated greywater were not significant (Table ٤.٩).

Figure (٤.٢٨) shows the percent of knowledge on greywater reuse for GWTP owner group at ٩٥٪ confidence interval. The percent of knowledge on greywater reuse decreased from about ٧٤ % household who owns GWTP group to ٢٦٪ in household who have no GWTP. The percent of environmental and agricultural service was decreased from about ٨١٪ household who owns GWTP to ١٩٪ in household who have no GWTP.



Figure(٤.٢٨): GWTP owner related toknowledge on greywater reuse and environmental and agriculture service.

The relations between the change in efficiency of the GWTPs with time(dependent factor) compared to the qualitative independent factors are indicated in Table (٤.١٠). The independent factors were: Fat removal, Air pump, Oil removal, use of detergent,Cleaning of babies and Food waste.

Table (٤.١٠): Chi-square for change in efficiency with time and qualitative independent factors

Item	Sig.	df	Value	Status
Fat removal	.٧٠٠	١	٠.٧٦٠	Not Significant
Air pump	.١٥١	١	٢.٦٨٣	Not Significant
Oil removal	٢.٤٤٣	٣	٢.٦٨٣	Not Significant
Use of detergent	.٢٩٢	٣	٣.٧٢٩	Not Significant
Cleaning of babies	.٧٨٩	٢	.٤٧٣	Not Significant
Food waste	.٧٨٩	٢	.٤٧٣	Not Significant

No significant relation between change in efficiency for GWTP owner and fat removal, air pump, oil removal, use of detergent, cleaning of babies and food waste.

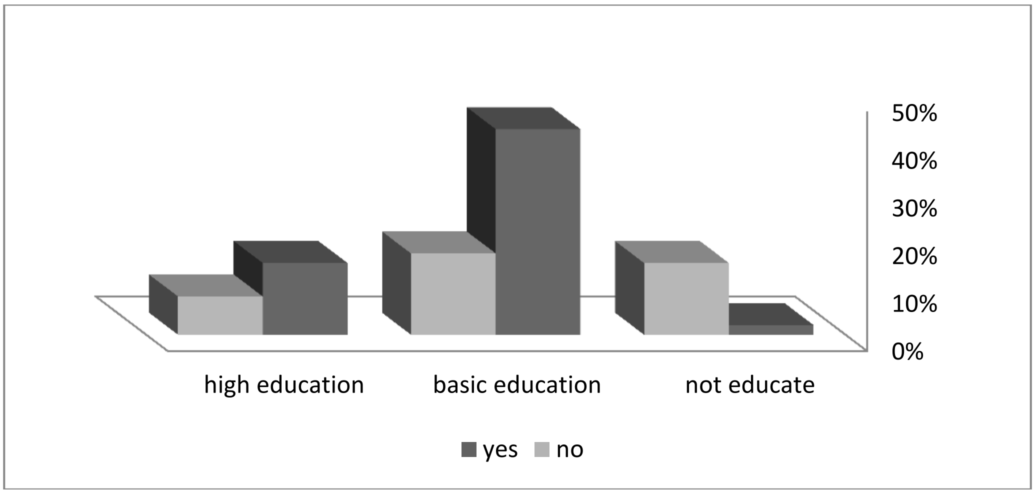
The relations between the interviewer acceptance of construction GWTP (dependent factor) compared the qualitative independent factors are indicated in table (٤.١١). The independent factors were: determine factor to not use treatment greywater in agriculture, Future worries about water quality and level of education

Table (٤.١١).Anova table for Acceptance of GWTP construction

Item	Sig	df	Value	Status
Determinant factor to not use treatment greywater in agriculture	٠٠٠	٤	٤٥	Significant
Future worries about water quality	٠٠٠	٧	٧٣	Significant
Level of education	٠.٠٢	٣	٩.٠٥٦	Significant

The acceptance of GWTP construction increased significantly (P < ٠.٠٥) for household who determine factor to not use treatment greywater in agriculture, future worries about water quality and level of education(Table ٤.١١).

Figure ٤.٢٩ shows the percent of the acceptance of GWTP construction for GWTP owner group at ٩٥٪ confidence interval. The percent of educated households were ٤٣٪ for basic education to household who accept GWTP construction, whereas ١٧٪ of the household who don't accept the construction of GWTP. The percent of educated households increased from about ٢٪ for uneducated households who accept GWTP construction to ١٥٪ for the household who don't accept GWTP construction (figure ٤.٢٨).



Figure(٤.٢٩): Acceptance of construction GWTP related to education

Figure(٤.٣٠) shows the percent of future worries for household acceptance of construction GWTP group at ٩٥٪ confidence interval. The percent were ٣٧٪ for health, ٨٪ for health and insect, ٥٪ for oder and insect, ١٠٪for pollution, religion and health. And this in agreement with Prathapar et al., (٢٠٠٥) where the results indicated that household do not accept wastewater reuse due to environmental degradation ٦١٪ and human health concerns ٤٧٪.

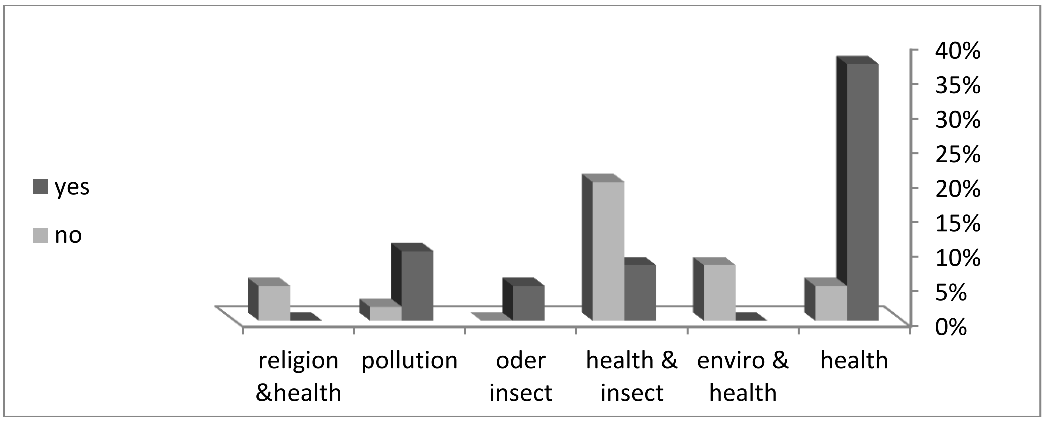


Figure (٤.٣٠): Acceptance of construction GWTP related to future worries

Figure (٤.٣١)Shows the percent of determined factor for household acceptance for construction GWTP group at ٩٥٪ confidence interval. The percent were ٣٣٪ for economic factor, ١٥٪ for health factor, ٦٪ for religion factor, ٦٪ for environmental factor and ٢٪ for health & economic. And this in agreement with Prathapar et al., (٢٠٠٥) as they found the main reason for not accepting unlimited use treated wastewater indentifed health ٤٠٪ and identified religion ٣٧%.

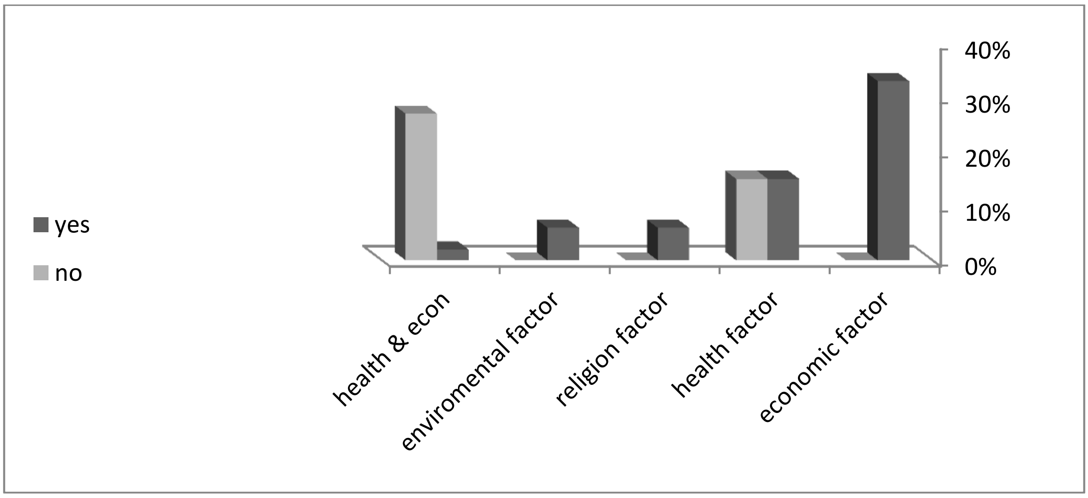


Figure (٤.٣١): Acceptance of construction GWTP related to determine factor

٤.٤.١١ Relations between dependent factor and quantitative factors (independent):

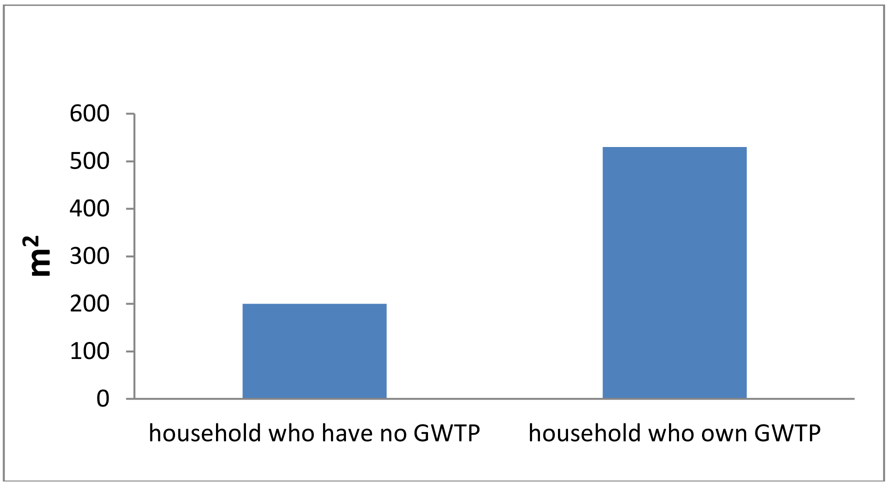
The relations between the people who use GWTPs for garden irrigation(dependent factor) compared to the quantitative independent factors are indicated in table (٤.١٢). The independent factors were: price, garden area, consumption rate and Number of time of discharge.

Table (٤.١٢): Anova table for the use of GWTPs for garden irrigation.

Anova	**Sig.**	**F**	**df**	**statues**
Price of water	.٨٥٦	٠.٣٣	٣٥.٤٧٤	Not Significant
Garden area	.٠١٢	٦.٩٣٢	٤٤	Significant
Consumption rate of water	.٦٢٥	.٢٤١	٦٨	Not Significant
Number of time of discharge	.٠٠٠	٢٦.٥٦٤	٦٩	Significant

The rates garden area and number of time discharge increased significantly in households whom own GWTP (P < ٠.٠٥) price, consumption rate were not significant (Table ٤.١٢).

Figure (٤.٣٢) shows the average garden area for GWTP owner group at ٩٥٪ confidence interval. The average garden area decreased from about ٥٣١ m٢ in the household who own GWTP group to ٢٠٠ m٢ in household who have no GWTP. The average of Number of time discharge decreased from about ٦ times for household who own GWTP.



Figure(٤.٣٢):Households who use GWTPs for garden irrigation related to garden area

Figure (٤.٣٣):The relation between household who use GWTPs for garden irrigation related to the number of time discharge

٤.٤.١٢ Relation between socioeconomic characterization of targeted group and chemical analysis

The result shows that ٩٠٪ of the household who own GWTPs indicated that the efficiency of GWTPs decrease by time and this agreed with the chemical analysis for the most analyzed indicators.

The total E. coli form and total coliform, were increased by the time (٢٠١٥) analyzed samples compared to the results during ٢٠١١ and this is might be due to no operation and maintenance of the air pump

Chapter Five
Conclusions and Recommendations

٥.١ Conclusions

The main finding of this research is that reusing treated grey water for irrigation is environmentally sound with respect to soil quality in the study area. The specific conclusions are:

- The pH, TDS, Na^+,$Ca^{٢+}$, Cl^-, BOD, $PO٤^{٢+}$ and $SO_٤^{٢-}$ fall within the Palestinian standard for treated wastewater (٢٠١٢).
- While $Mg^{٢+}$,$NO^-_٣$ and COD were higher than the standard.

- Soil quality remained non affected by the irrigation with treated graywater after five years**.**
- Soil pH and Ec remained within the normal range.
- The average concentrations of Zn, Cu, Cr and Mn in the soil irrigated by treated greywater were not significantly higher than the standard. The results also do not show any relationship between long time application of treated greywater and heavy metals accumulations in the soil.

Recommendation:

This study recommends the use of treated greywater for agriculture home garden. This decentralized small-scale technology can help to alleviate water insecurity in rural communities.

It is recommended to increase the education programs and public awareness campaigns that stress the safety of the system and its effectiveness in crop irrigation. Targeted public awareness campaigns reaching out to the social groups responsible for water management. which is used by most rural communities in Palestine is fraught with

Public health risks of the current cesspit system in Palestine can beeliminated through the implementation of greywater recycling systems where cesspit systems fail to protect Palestine’s vital freshwater resources.

Some rural Areas pays a high price for water and this form chronic water insecurity. Treated greywater reduce the problem of water scarcity.

Women play a key role in the maintenance, sustainability and operation of the greywater recycling systems. The empowerment of women will lead to the sustainability of the station.

Increase the intervals of the extension services for the use of treated graywater in the irrigation of home garden.

It is recommended to disseminate constructed wet land system for household don't connected to the derange system.

Maintenance and flow up for the treatment unit increase the efficiency .

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Appendix (١)

لاستبيان: (   )

بسم الله الرحمن الرحيم

إستبيان

دراسة الجانب الإقتصادي والإجتماعي لمستخدمي المياه العادمة الرمادية المعالجة في محافظات جنين، طوباس.

ملاحظة: البيانات الوارد في هذه الإستمارة ذات طابع سرية ولا تستخدم إلا لأغراض البحث العلمي.

أسم المزارع: ....

أسم الباحث: ....

تاريخ الزيارة: ....

اذار/ ٢٠١٥

اولا: معلومات عامة:

١.المحافظة: .... ٢. القرية: .... ٣ .أسم رب لاسرة....................... .

٤- الجنس: ١- ذكر ٢- أنثى ٥- البيت الذي تسكنه: ١/ ملك... ٢/ مستأجر

٦- نوع السكن: ١/ شقة........... ٢/منزل منفصل..........

٧ - المستوى التعليمي لرب الاسرة.

١/ امي ٢/ يقرأ ويكتب ٣/ اساسي ٤/ جامعي واكثر

٨- عدد أفراد الأسرة ذكور .... إناث .... الإجمالي .....

٩- المهنة ١- موظف ٢- ربة بيت ٣- عامل

١٠- الدخل الشهري للاسره بالشيقل -----

١١. هل يتوفر لديك المرافق التالية:

١/ شبكة كهرباء ١ - نعم ٢- لا

٢/ شبكة مياه ١ - نعم ٢- لا

٤/ شبكة مجاري ١ - نعم ٢- لا

٥ / حديقة منزليه ١ - نعم ٢- لا

١٢/ اذا كانت لديك حديقة منزلية ما هو إجمالي مساحة الحديقة لديك :.............م٢

ثانيا : الوعي البيئي:

١٣. هل هناك جهات تقدم لك توعية بيئية و زراعية: ١- نعم ٢- لا

١٤. اذا كانت الاجابة السابقة نعم ما هو مستوى هذه الخدمة المقدمة لك:

١/ ضعيف ٢/ مقبول ٣/ جيد ٤/ ممتاز

١٥. إذا حدثت عنك مشكلة طارئة أثناء العمل لمن تتوجه:

١/ وزارة الزراعة ٢/ شركات خاصة ٣/ جيران ٤/ أحاول حلها لوحدي

١٦٠- هل تلقيت أي معلومات ارشاديه عن المياه الرماديه

١- نعم ٢- لا

١٧- اذا كانت الاجابة نعم ما طبيعة هذه المعلومات

١- ورشات عمل ٢- زيارات ميدانيه ٣- دورات تدريبيه ٤- منشورات

١٨ -. ما مدى معرفتك بالمياه الرمادية ١/ لا يوجد ٢/ قليل ٣/ جيدة

١٩- ماهو مصدر معلوماتك حول استخدام المياه الرماديه

١- وزارة الزراعه ٢- المؤسسات الاهلية ٣- جيران او اقارب ٤- لا يوجد لدي معلومات

ثالثا : المياه

٢٠- مصدر المياه ١/ شبكة مياه.. ٢/ آبار جمع. ٣/ ينابيع... ٤/غير ذلك....٥...شراء بالصهريج......

٢١- ما هي المشاكل التي تواجها في خدمات المياه:

١ النقص ٢. الانقطاع ٣. صعوبة ايصالها ٤.ارتفاع الاسعار ٥. كل ما ذكر ٦. غير ذلك..تدني نوعية المياه او تلوثها

٢٢- معدل الاستهلاك الشهري للمياه في الوقت الحالي م٣

٢٣. سعر المتر المكعب من المياه............. شيقل

. ٢٤- اهم مجالات استخدام المياه:

١/ زراعة ٢/ شرب الماشية ٣/ صناعة ٤/ استخدام منزلي ٥/ غير ذلك ....

-٢٥- ماهي طريقة الري المستخدمة لري الحديقه المنزليه ١- التنقيط ٢- غير ذلك حدد-----------------

٢٦- ماهي العوامل المحددة لعدم استخدام المياه الرماديه المعالجة في حديقة المنزل

١- عوامل اجتماعية ٢- عوامل اقتصادية ٣- عوامل صحية ٤- عوامل دينية ٥- عوامل بيئية

٢٧- هل لديك استعداد لشراء محاصيل مرويه اشجار او اعلاف) على مياه رمادية معالجة ١- نعم ٢- لا

٢٨- ما هي التخوفات المستقبلية لانشاء محطات لمعالجة المياه العادمة الرمادية؟

....

....

٢٩- هل يوجد فصل للمياه الرمادية عن السوداء(التواليت) في المنزل ١ - نعم ٢- لا

٣٠- هل لديك محطة تنقية للمياه الرمادية في المنزل ١- نعم ٢- لا

<u>اذا كانت الاجابة نعم اجب عن الجزء الاول اذا كانت الاجابة لا انتقل الى الجزء التاني</u>

الجزء الاول

٣١- . اذا كانت الإجابة نعم ما هي الأصناف التي قمت بزراعتها:

١/ خضار ٢/ أشجار ٣/ أزهار ٤/ غير ذلك

٣٢- هل تذهب المياه السوداء الى حفرة امتصاصيه ١ - نعم ٢- لا

٣٣- ماهي مساحة هذه الحفرة الطول ٠٠٠٠٠٠٠ العرض٠٠٠٠٠٠٠٠٠ الارتفاع ٠٠٠٠٠

٣٤- هل تحتاج الى نضح مستمر ١ - نعم ٢- لا

٣٥- كم مره تحتاج الى نضح الحفره خلال السنة ٠٠٠٠٠٠٠٠

٣٦- ماهي تكلفة النضح لكل مره...................... با لشيقل

٣٧- ما هي المحاصيل التي تزرع بها الحديقة المنزلية:

١/ خضار ٢/ أشجار ٣/ أزهار ٤/ غير ذلك

٣٨- ماهي مساحة وحدة التنقيه ٠الطول ٠٠٠٠٠٠٠٠ العرض ٠٠٠٠٠٠٠ الارتفاع ٠٠٠٠٠٠

٣٩- هل تلقيت مساعدات من أي جهة لانشاء المحطة ١- نعم ٢- لا

٤٠- اذا كانت الاجابه لا ماهي التكلفه الاجماليه لانشاء المحطة بالشيقل ٠٠٠٠٠٠٠٠٠٠٠

٤١- هل تحتاج المحطة الى صيانه مستمره ١- نعم ٢- لا

٤٢- هل تواجه أي مشاكل من استخدام محطة معلجة المياه الرماديه ١- نعم ٢- لا

٤٣ – اذا كانت الاجابه نعم ما هي نوع هذه المشاكل ١-روائح ٢-حشرات ٣- صيانه ٤- اخرى حدد..........

٤٤- للمراه هل تقومي بكل مما يلى

	اوافق بشده	اوافق	لا راي	اعارض	اعارض بشدة
اقوم بالتخلص من الزيوت القلى في المجلى					
استخدم المدهش ومزيل الدهون في تنظيف المغاسل والمجلى					
اتخلص من بقايا دهون االلحوم في المجلى					
اقوم بتنظيف الاطفال على المغاسل					
هل تقومي برمي مخلفات الطعام في المجلى					
التخلص من السوائل الكيميائيه السامه في المغاسل والمجلى					

٤٤- هل هناك مضخة هواء للمحطه ١- نعم ٢- لا

٤٥- هل تقوم تقوم بصيانتها باستمرار ١- نعم ٢- لا

٤٦-هل تتوقع أي اثار سلبيه لهذه المحطات ١- بيئيه ٢- صحيه ٣- اقتصادية

٤٧- هل تقوم بازالة الدهون من المحطة باستمرار ١- نعم ٢- لا

٤٨- هل تستخدم الاسمدة بكثره في حديقتك ١- نعم ٢- لا

٤٩-اذا كانت الاجابة نعم ماهي كمية الا سمدة المستخدمة خلال السنه .... كغم ٠

٥٠- قبل استخدام محطة التنقية كم كانت كمية الاسمدة المستخدمه .... كغم

٥٠- هل زادت كمية لانتاج لديك بعد استخدامك للمياه المعالجة الرمادية في ري الحديقة المنزلية ١- نعم ٢- لا

٥١- اذا كانت الاجابة نعم ما مقدار هذة الزيادة ٧٠% ٢- ٥٠% ٣- ٢٥%

٥٢-- هل تخجل من الناس بسبب اعادة استخدام المياه المعالجة الرماديه لري المزرعة ١- نعم ٢- لا

٥٣- هل يوجد صعوبة في تسويق المنتجات المروية بالمياه الرمادية: ١- نعم ٢- لا

٥٤- كمية المياه الرمادية المعالجة كافيه للمساحة المزروعة ١- نعم ٢- لا

٥٥- هل تحتاج الى ري تكميلى بمياه عذبة ١- نعم ٢- لا

٥٦- اذا كانت الاجابه نعم كمية المياه المستخدمة في الري التكميلى -------------- م٣

٥٧- ماهي كميه المياه التي كنت تستهلكها لري الحديقة المنزليه قبل انشاء المحطه التنقية م٣

٥٨- ماهي كمية المياه التي تستهلكها لري الحديقه بعد انشاء المحطه التنقية م٣

٥٩- هل زاد انتاج المحاصل بعد استخدام المياه الرماديه المعالجه في ري المزروعات ١- نعم ٢- لا

٦٠- هل تشعر بتغير كفاءة المحطة بعد سنوات من الاستخدام ١- نعم ٢- لا

٦١- ما هو مدى رضاك عن كفاءة عمل محطة التنقية لديك ١-راضي جداً - ٢راضي - ٣غير راضي

٦٢- هل هناك توفير في كمية المياه العذبة المستخدمة بعد انشاء محطة التنقية نعم لا كم النسبة.........م٣...

الجزء الثاني

٦٣- ما هو نوع الحفرة الامتصاصية؟ ١ - حفرة منفذة - ٢ .حفرة مصمتة (غير منفذة ٣ .(غير ذلك حدد................

٦٤- ما هي أبعاد الحفرة الامتصاصية بالأمتار؟ - ١الطول - ٢ .... :العرض – ٣ ....العمق

٦٥- كيف كانت الطبيعة الجيولوجية للحفرة عند حفرها؟ ١- تراب ٢- صخر قاسي ٣- صخر طري

٦٦- ما هي تكلفة إنشاء الحفرة الامتصاصية؟ بالشيكل.....................................

٦٧- هل يتم نضح الحفرة الامتصاصية؟ ١- نعم ٢- لا

٦٨- كم مرة يتم نضح الحفرة الامتصاصية خلال السنة في الفترة الحالية؟

٦٩- ماهي تكلفة النضح لكل مرة .... بالشيقل

٧٠- ما هي تكلفة نضح الحفرة الامتصاصية في كل مرة يتم نضحها بالشيكل....................................

٧١- ما مدى انزعاج الأسرة والجيران من عملية نضح الحفرة الإمتصاصية؟ ١-كبير ٢- متوسط ٣- قليل ٤- لا تنزعج

٧٢- ما هو مستوى الصوت الذي ينتج ضمن محيط المنزل من عملية نضح الحفرة الإمتصاصية؟

١- صوت لا يذكر ٢- صوت مقبول ٣ -صوت عالي –غير مقبول

٧٣- هل يتم التخلص من محتوى الحفرة الامتصاصية بطريقة أخرى غير النضح؟ ١- نعم - ٢- لا

٧٤- إذا كان جواب نعم، فما هي هذه الطريقة؟ ....

٧٥- ما هو المبلغ الذي تستعد لدفعه من أجل التخلص من الحفرة الامتصاصية وايجاد بديل لها؟ (بالشيكل/شهر

٧٦- هل يوجد بئر لجمع مياه الأمطار محاذي للمنزل؟ - ١نعم ٢- لا

٧٧- ما هي مادة إنشاء البئر؟ ١ - باطون - ٢صخر - ٣ -مختلط

٧٨- كم تبعد الحفرة الامتصاصية عن البئر؟ م

٧٩- ما هو مصدر ري المزروعات في الحديقة؟ - ١شبكة المياه - ٢ .البئر - ٣ .المياه الرمادية غير المعالجة. (مياه الغسيل والجلي)– ٤ لا تحتاج مياه

٨٠- هل كمية المياه المتوفرة لري المزروعات كافية؟ ١- نعم ٢- لا

٨١- ما هو سعر المتر المكعب من المياه .... شيقل

٨٢- ماهي كمية الاسمدة المستخدمه خلال السنه في الحديقه المنزلية ....كغم

٨٣- ما مدى رضاك عن نظام الصرف الصحي الحالي؟ - ١راضي جداً - ٢راضي - ٣غير راضي

٨٤- في حال عدم الرضى .ما هو سبب عدم الرضى؟

٨٥- هل تعرف عن أنظمة معالجة المياه العادمة الرمادية؟ ١-نعم ٢- لا

٨٦- هل تقبل بانشاء محطة معالجة للمياه العادمة الرمادية ؟

٨٧- هل تقبل باعادة استخدام المياه المعالجة الرمادية في ري المزروعات في الحديقة المنزلية؟ ١- نعم ٢- لا

٨٨- اذا كانت الاجابة لا، ما هي أسباب عدم قبولك لإنشاء محطات معالجة المياه الرمادية؟.........................٠

Appendix (٢)

Palestinian National Authority

Ministry of Environmental Affairs

السلطة الوطنية الفلسطينية

وزارة شئون البيئة

المعايير الفلسطينية

للمياه العادمة المعالجة

مسودة

Palestinian Standards for Treated Wastewater

"Draft"

المحتويــات

١- المجال

تختص هذه المواصفة بالاشتراطات الواجب توفرها في المياه العادمة المعالجة و الخارجة من محطات المياه العادمة التي يتم تصريفها أو إعادة استعمالها في الأوجه المبينة في الجدول (١).

التعاريف

المياه العادمة : هي المياه الملوثة بفعل مواد صلبة أو سائلة أو غازية أو كائنات دقيقة نتجت أو تخلفت عن المنازل أو المباني أو المنشآت المختلفة.

المياه العادمة المعالجة : هي المياه الناتجة عن محطات معالجة المياه العادمة و المطابقة لهذه المواصفة، ما لم تختلط بمياه من مصادر أخرى.

الاشتراطات العامة

يجب أن تطابق المياه العادمة المعالجة الخواص الموضحة في الجدول رقم (١) حسب الاستعمال النهائي المخطط له.

يجب إيقاف الري قبل جني المحصول بأسبوعين عند استعمال المياه المعالجة لغايات ري الأشجار المثمرة و المحاصيل الحقلية و الأعلاف قبل رعيها و استبعاد الثمار الساقطة و الملامسة للأرض.

يجب الأخذ بعين الاعتبار حساسية المزروعات لبعض الخواص و العناصر في المياه المعالجة عند اختيار المحصول و مراعاة التأثير السلبي على خواص التربة.

لا يسمح باستعمال نظام الري بالرشاشات.

لا يسمح باستعمال هذه المياه لري جميع أنواع الخضار.

يجب استعمال الأنابيب عند نقل المياه المعالجة في مناطق تربة ذات نفاذية عالية و التي قد تؤثر على مياه الخزان الجوفي أو المياه السطحية المستخدمة للشرب.

لا يسمح بتخفيف هذه المياه و ذلك بخلطها في موقع محطة المعالجة مع مياه نقية بهدف تحقيق الاشتراطات الواردة في هذه المعايير.

لا يسمح باستعمال المياه المعالجة لتغذية الخزان الجوفي عن طريق الحقن المباشر.

عند تصريف المياه العادمة المعالجة إلى البحر يجب أن يكون مخرج الأنبوب على بعد ٥٠٠ متر على الأقل من الشاطئ.

الاشتراطات القياسية

يجب أن تتوافر في المياه العادمة المعالجة الاشتراطات القياسية الواردة في الجدول رقم (١) و حسب الاستعمال النهائي لها و تعتمد على ما يلي:-

أن تكون العينات ممثلة و مجمعة على مدار اليوم باستثناء الخواص التي يحتاج تحليلها إلى عينات منفردة و أن يكون عدد العينات و الفترة الزمنية لأخذ العينات كما هو موضح في الجدول رقم (٢).

لأغراض تقييم نوعية المياه المعالجة للأغراض المختلفة الموضحة في الجدول رقم (١) تعتمد الفترات الزمنية الموضحة في الجدول رقم (٢).

أن لا تزيد نسبة العينات المتجاوزة للاشتراطات المبينة في الجدول رقم (١) عن ٢٠% من عدد العينات التي تم جمعها خلال فترة التقييم المبينة في الجدول رقم (٢) على ألا تزيد قيمة التجاوز في أي خاصية عن خمسة أضعاف الحد المسموح به في الجدول رقم (١).

جدول(١): الاشتراطات القياسية للمياه العادمة المعالجة كحد أقصى ما لم يذكر خلاف ذلك:

الخاصية ملجم/لتر ما لم يذكر غير ذلك	تصريف إلى البحار على بعد ٥٠٠ متر	تغذية الخزان الجوفي بالترشيح	ري أعلاف جافة	ري أعلاف خضراء	ري حدائق ملاعب و متنزهات	ري محاصيل صناعية و حبوب	ري أشجار حرجية و غابات	ري أشجار حمضيات	ري أشجار زيتون	ري أشجار لوزيات
الأكسجين الممتص حيويا BOD_5	٦٠	٤٠	٦٠	٤٥	٤٠	٦٠	٦٠	٤٥	٤٥	٤٥
الأكسجين الممتص كيميائياً COD	٢٠٠	١٥٠	٢٠٠	١٥٠	١٥٠	٢٠٠	٢٠٠	١٥٠	١٥٠	١٥٠
الأكسجين المذاب DO	أكثر من ١	أكثر من ١	أكثر من ٠.٥	أكثر من ٠.٥	أكثر من ٠.٥	أكثر من ٠.٥	أكثر من ٠.٥	أكثر من ٠.٥	أكثر من ٠.٥	أكثر من ٠.٥
المواد الذائبة الكلية TDS	-	١٥٠٠	١٥٠٠	١٥٠٠	١٢٠٠	١٥٠٠	١٥٠٠	١٥٠٠	١٥٠٠	١٥٠٠
المواد الصلبة العالقة الكلية TSS	٦٠	٥٠	٥٠	٤٠	٣٠	٥٠	٥٠	٤٠	٤٠	٤٠
الرقم الهيدروجيني pH	٦-٩	٦-٩	٦-٩	٦-٩	٦-٩	٦-٩	٦-٩	٦-٩	٦-٩	٦-٩
اللون Color (PCU)	خالية	خالية	خالية	خالية	خالية	خالية	خالية	خالية	خالية	خالية
الزيوت والشحوم Fat Oil &Greas	١٠	٠	٥	٥	٥	٥	٥	٥	٥	٥
الفينول Phenol	١	٠.٠٠٢	٠.٠٠٢	٠.٠٠٢	٠.٠٠٢	٠.٠٠٢	٠.٠٠٢	٠.٠٠٢	٠.٠٠٢	٠.٠٠٢
المنظفات الصناعية MBAS	٢٥	٥	١٥	١٥	١٥	١٥	١٥	١٥	١٥	١٥
النترات–نيتروجين NO_3 (N)	٢٥	١٥	٥٠	٥٠	٥٠	٥٠	٥٠	٥٠	٥٠	٥٠
الأمونيوم–نيتروجين NH_4 (N)	٥	١٠	-	-	٥٠	-	-	-	-	-

النتروجين العضوي.نيتروجين **O.K.N**	١٠	١٠	٥٠	٥٠	٥٠	٥٠	٥٠	٥٠	٥٠	٥٠
الفوسفات–فسفور **(P) PO٤**	٥	١٥	٣٠	٣٠	٣٠	٣٠	٣٠	٣٠	٣٠	٣٠
الكلوريد **Cl**	-	٦٠٠	٥٠٠	٥٠٠	٣٥٠	٥٠٠	٥٠٠	٤٠٠	٦٠٠	٤٠٠
الكبريتات **SO٤**	١٠٠٠	١٠٠٠	٥٠٠	٥٠٠	٥٠٠	٥٠٠	٥٠٠	٥٠٠	٥٠٠	٥٠٠
الصوديوم **Na**	-	٢٣٠	٢٠٠	٢٠٠	٢٠٠	٢٠٠	٢٠٠	٢٠٠	٢٠٠	٢٠٠
الماغنسيوم **Mg**	-	١٥٠	٦٠	٦٠	٦٠	٦٠	٦٠	٦٠	٦٠	٦٠
الكالسيوم **Ca**	-	٤٠٠	٤٠٠	٤٠٠	٤٠٠	٤٠٠	٤٠٠	٤٠٠	٤٠٠	٤٠٠
نسبة ادمصاص الصوديوم **SAR**	-	٩	٩	٩	١٠	٩	٩	٩	٩	٩

الخاصية ملجم/لتر ما لم يذكر غير ذلك	تصريف إلى البحار على بعد ٥٠٠ متر	تغذية الخزان الجوفي بالترشيح	ري أعلاف جافة	ري أعلاف خضراء	ري حدائق ملاعب و متنزهات	ري محاصيل صناعية و حبوب	ري أشجار حرجية و غابات	ري أشجار حمضيات	ري أشجار زيتون	ري أشجار لوزيات
الألمنيوم Al	٥	١	٥	٥	٥	٥	٥	٥	٥	٥
الزرنيخ Ar	٠.٠٥	٠.٠٥	٠.١	٠.١	٠.١	٠.١	٠.١	٠.١	٠.١	٠.١
النحاس Cu	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢
الحديد Fe	٢	٢	٥	٥	٥	٥	٥	٥	٥	٥
المنغنيز Mn	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢
النيكل Ni	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢	٠.٢
الرصاص Pb	٠.١	٠.١	١	١	٠.١	١	١	١	١	١
السيلينيوم Se	٠.٠٢	٠.٠٢	٠.٠٢	٠.٠٢	٠.٠٢	٠.٠٢	٠.٠٢	٠.٠٢	٠.٠٢	٠.٠٢
الكادميوم Cd	٠.٠١	٠.٠١	٠.٠١	٠.٠١	٠.٠١	٠.٠١	٠.٠١	٠.٠١	٠.٠١	٠.٠١
الزنك Zn	٥	٥	٢	٢	٢	٢	٢	٢	٢	٢
السيانيد CN	٠.١	٠.١	٠.٠٥	٠.٠٥	٠.٠٥	٠.٠٥	٠.٠٥	٠.٠٥	٠.٠٥	٠.٠٥
الكروم Cr	٠.٥	٠.٠٥	٠.١	٠.١	٠.١	٠.١	٠.١	٠.١	٠.١	٠.١
الزئبق Hg	٠.٠٠١	٠.٠٠١	٠.٠٠١	٠.٠٠١	٠.٠٠١	٠.٠٠١	٠.٠٠١	٠.٠٠١	٠.٠٠١	٠.٠٠١
كوبالت Co	١	٠.٠٥	٠.٠٥	٠.٠٥	٠.٠٥	٠.٠٥	٠.٠٥	٠.٠٥	٠.٠٥	٠.٠٥
البورون B	٢	١	٠.٧	٠.٧	٠.٧	٠.٧	٠.٧	٠.٧	٠.٧	٠.٧
بكتيريا القولون البرازية Faecal Coliform (CFU/١٠٠ml)	٥٠٠٠٠	١٠٠٠	١٠٠٠	١٠٠٠	٢٠٠	١٠٠٠	١٠٠٠	١٠٠٠	١٠٠٠	١٠٠٠

الجراثيم الممرضة **Pathogens**	**خالية**	**خالية**	**خالية**	**خالية**	**خالية**	**خالية**	**خالية**	**خالية**	**خالية**	**خالية**
الأميبا و الجارديا **Amoeba & Gardia (Cyst/L)**	**خالية**	**خالية**	-	-	**خالية**	-	-	-	-	-
الديدان الدائرية النيماتودا **Nematodes (Eggs/L)**	**أقل من ١**	**أقل من ١**	**أقل من ١**	**أقل من ١**	**أقل من ١**	**أقل من ١**	**أقل من ١**	**أقل من ١**	**أقل من ١**	**أقل من ١**

(-) : غير محددة

جدول (٢) مراقبة نوعية

الرقم	الخاصية	تكرارية العينات	فترة التقييم*
١-	**الفحوصات الميكروبيولوجية**		
	- التحري عن جراثيم القولون و القولون البرازية	عينة / أسبوعين	٣ شهور
	- التحري عن الجراثيم الممرضة	عينة / أسبوعين / صيفاً** عينة / شهر / شتاءً***	في حالة ظهور نتيجة أي عينة إيجابية يتم أخذ عينتين إضافيتين بفارق يومين بينهما، و إذا كانت نتائج هذه العينات إيجابية يتم إيقاف استعمال المياه للري لحين زوال التلوث.
٢-	**الفحوصات البيولوجية**		
	– التحري عن الديدان المعوية و الأوليات	عينة / شهرين	سنة
٣-	**الفحوصات الكيميائية**		
	أ. الفحوصات الروتينية	عينة / شهر	سنة
	ب. الفحوصات الخاصة بالعناصر النادرة و الثقيلة	عينة / سنة	سنة

(*) فترة التقييم: تعتمد الفترة السابقة لمرحلة التقييم أساساً للحكم على نوعية المياه.

(**) صيفاً: الفترة من بداية شهر أيار و حتى نهاية شهر تشرين أول.

(***) شتاءً: الفترة من بداية شهر تشرين ثاني و حتى نهاية شهر نيسان.

٢ – المراجـع

١ – المواصفة الفلسطينية "المياه العادمة الخارجة من المصانع" رقم (م ف ٢٢٧) لعام ١٩٩٨

٢ – المواصفة الأردنية "المياه– مياه الصرف الصحي المعالجة" رقم (١٩٩٥/٨٩٣)

٣ – قانون البيئة المصري "المعايير و المواصفات لبعض المواد عند تصريفها في البيئة البحرية")

٤ –قانون البيئة العماني " القواعد الخاصة بتصريف المواد المتدفقة السائلة في البيئة البحرية

٥ – منظمة الأغذية و الزراعة FAO Guidelines for Agriculture لعام ١٩٩١

٣- المصطلحـات الفنيـة

١- الأكسجين الممتص حيوياً	Bio-Chemical Oxygen Demand (B.O.D)٥
٢- الأكسجين الممتص كيميائياً	Chemical Oxygen Demand (C.O.D)
٣- الأكسجين المذاب	Dissolved Oxygen
٤- عينات منفردة	Grab samples
٥- عينة مجمعة	Composite sample
٦- عصيات القولون	Faecal coliforms
٧- الديدان المعوية	Intestinal nematodes
٨- المواد العالقة الكلية	Total Suspended Solids (T.S.S)
٩- المواد الذائبة الكلية	Total Dissolved Solids (T.D.S)
١٠- الزيوت و الشحوم	Fat Oil and Grease (FOG)
١١-المنظفات الصناعية	Methylene Blue Active Substance(MBAS) (foaming agent)

٧-الجهات المشاركة

١. وزارة شئون البيئة
٢. وزارة الصحة
٣. وزارة الزراعة
٤. مؤسسة المواصفات والمقاييس
٥. سلطة المياه
٦. بلدية غزة
٧. الجامعة الاسلامية
٨. جامعة الأزهر
٩. مختبر جامعة بير زيت

جامعة النجاح الوطنية
كلية الدراسات العليا

تقييم مؤشرات الأداء للاستخدام الأمن للمياه الرمادية المعالجة في شمال الضفة الغربية

إعداد
عبير عفيف برهان جمعة

إشراف
أ.د مروان حداد
د . هبة الفارس

قدمت هذه الاطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في العلوم البيئية بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين

٢٠١٦

تقييم مؤشرات الأداء للاستخدام الأمن للمياه الرمادية المعالجة في شمال الضفة الغربية

إعداد

عبير عفيف برهان جمعة

إشراف

أ.د مروان حداد

د . هبة الفارس

الملخص

تعاني فلسطين من حساسية و ندرة مصادر المياه الجوفية التقليدية وتعتبر المياه الرمادية والتي تشكل من ٥٠-٨٠% من المياه المنزلية العادمة مصدر بديل للمياه.

وتهدف هذه الدراسة إلى تقيم استخدام المياه الرمادية المعالجة على المدى القصير وعلى المدى الطويل والقبول المجتمعي لاستخدام هذه المحطات .

استخدمت مؤشرات تقيم الأداء لتقيم جودة وكفاءة تنفيذ محطات معالجة المياه الرمادية في شمال الضفة الغربية. تم تقيم ستة محطات لمعالجة المياه الرمادية من محافظتي جنين وطوباس(نظام الأراضي الرطبة) استخدمت لزراعة أشجار الفاكهة (الحمضيات والزيتون) والأعلاف (الذرة) صممت الاستمارات من اجل المسح الميداني ووزعت على المستفيدين تم جمع البيانات وتحليلها باستخدام Excel and SPSS

المؤشرات على المدى القصير كانت تشمل التحليل الكيميائي للمياه قبل وبعد المعالجة خلال شهري حزيران وتموز

المؤشرات pH , TDS, Na^+ ,Ca^{2+} ,Cl^- ,BOD ,PO_4^{3+}, SO_4^{2-}

كانت تقع ضمن المعيار الفلسطيني لمياه الصرف الصحي المعالجة . حيث بلغت معدلاتها على التوالي ١٣٩ ,٧.٦٩ ,١٧٨ ,٢٢٤ ,٦٥.٦ ,١٢٨.٢ ,١٠٢٤.٢٧ ,٧.٥

بينما كانت المعدلات لل Mg^{2+}, NO_3^-, COD أعلى من المعيار حيث بلغت

على التوالي ٤٠٠.٠ ,٧٧.٨ ,٢٨٨.٣

بالنسبة للمؤشرات على المدى الطويل فكانت تشمل نتائج تحليل المياه في ٢٠١١

والتي نفذت من خلال المركز الوطني للبحوث الزراعية NARC ومقارنتها مع نتائج تحليل المياه في ٢٠١٥ ودراسة تأثير الري باستخدام المياه الرمادية المعالجة على الخصائص الكيميائية للتربة.

خلال عام ٢٠١٥ كانت كفاءة إزالة Total Coliform بنسبة ٣٣.٣% مقارنة ب ٨٧ % في عام ٢٠١١. وكان الانخفاض في ٢٠١٥ بنسبة ٥٣.٣% . كانت كفاءة E.coli %٣٧.٣ مقارنة ب ٥٥.٣% في عام ٢٠١١. وكان الانخفاض ١٨٪. وكانت كفاءة BOD ٧٠.٨٪في عام ٢٠١٥ مقارنة مع ٧٥.٨٪في عام ٢٠١١. وكان الانخفاض بنسبة ٥٪. وكانت كفاءة EC ٩.٨٪ في عام ٢٠١٥ مقارنة مع ٢٧.٣٪ في عام ٢٠١١. وكان الانخفاض ١٧.٥٪.TDS قلت بنسبة ١٦.٣٪ ،المؤشرات الهامة مثل BOD، TDS، EC و E .coli أظهرت انخفاض في كفاءة المحطات مع الوقت، لكنه لا يزال مقبولا ضمن المعايير الفلسطينية .

تم جمع ثلاث عينات من التربة من حدائق مروية بمياه رمادية معالجة على عمق ٠–٣٠ سم وعمق ٣٠–٦٠ سم ومقارنتها بعينة مروية بمياه عذبة . وكانت النتائج pH ٦.٦٧ وEc كانت ٢.٦٥ حيث كانت مقبولة بالنسبة للمعاير الفلسطينية . أما بالنسبة لتراكم المعادن Zn, Cu, Cr, Mn فقد بلغت معدلاتها في التربة على التوالي ٥.١٦, ٠.٦٩, ٠.٤٤, ٣.٣ وهي ليست أعلى من المعدل. النتائج أيضا لا تظهر أي علاقة بين استخدام المياه الرمادية المعالجة في التربة على المدى الطويل وتراكمات المعادن الثقيلة في التربة .

٦٠٪ من مجموع الأفراد ليس لديهم معلومات عن المياه الرمادية، وهذا يعكس عدم وجود حملات التوعية والإرشاد. وتبين الدراسة أن ما يقرب من ٧٦٪ من لأفراد تواجه نقصا في المياه وأفاد نفس النسبة أن أسعار المياه تعتبر عائقا رئيسيا لديهم للتعامل معها. متوسط عدد مرات الرشح هو ٤.٦ ومتوسط التكلفة ٩٥ شيكل في كل مرة. وهذا يعكس ارتفاع تكلفة النضح. وعلاوة على ذلك أفاد ٣٣٪ من أصحاب وحدات المعالجة أن الوحدات تحتاج إلى صيانة منتظمة. وذكر حوالي ٧١٪ من أصحاب وحدات المعالجة أن الوحدات زادت إنتاج المحاصيل في حديقة المنزل. وبالإضافة إلى ذلك، أشار ٨٩٪ منهم انخفاض في كفاءة وحدات المعالجة مع مرور الوقت وهذا ما يتفق مع التحليل الكيميائي.

٣٧٪ اتخذوا العامل الاقتصادي محددا لنشر وحدات المعالجة بين المجتمعات. وكان رضا الناس عن تطبيق وحدات معالجة المياه المادية واعدة جدا، حيث أظهرت غالبية المستفيدين٧١.٤ ٪ راضون عن وحدات معالجة المياه الرمادية .