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Feasibility of Using Reverse Osmosis as Post-Treatment of Wastewater in Gaza Wastewater Plants

دراسة جدوى استخدام تقنية التناضح العكسي لمعالجة مياه الصرف الصحي الناتجة من محطات المعالجة

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إقرار

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Abstract

Wastewater reclamation has become a viable alternative to supplement water supplies in water scarcity areas. Current chemical, physical and biological wastewater treatment techniques don't always duly remove all biogenic elements (nitrates, ammonia and phosphates) and other pollutants to proper reuse wastewater.

Modern methods like membrane technologies recently gained the acceptance and is being used in commercial large-scale worldwide. Reverse osmosis can offer high removal rates with low energy consumption for many of contaminants and pollutants such as dissolved solids, heavy metals, organic pollutants, viruses, bacteria, and other dissolved contaminants. However, to apply reverse osmosis to treat wastewater successfully, appropriate pretreatment is required to decrease fouling rates for RO membranes and extend its life.

Our research aims to assess the performance of using RO as post treatment for Gaza wastewater treatment plants and compare it with Palestinian standards for non-potable usage as agriculture and groundwater recharging. Also, the research aims to estimate the total cost of applying this extra advanced technology.

The experimental work using RO membrane unit as a post treatment was conducted in two trials. In each trial, the partially treated wastewater was collected from GWWTP effluent and fed to sand filter then to three stages of micro-filtration membranes as pretreatment then to the RO membrane unit. The BOD, TSS, TDS, FC, NO3, EC pH and Temperature was tested at every stage of the experiment system.

Results shows that RO with its associated pretreatment treatment has ability to remove 100% of BOD, 92% of TSS, 100% of Nitrate, 100% of FC, and 88% of TDS. Furthermore, cost analysis for using RO as post treatment for GWWTPs was done. Results shows that the cost of 1m3 of treated wastewater less than 0.9$ and consume 0.7 Kwh.

ملخص الدراسة

اكتسبت إعادة استخدام مياه الصرف الصحي المعالجة أهمية كبيرة وأصبحت تعتبر مصدر لاستكمال النقص في المياه خصوصا في المناطق الفقيرة بالمياه. إن أحدث تقنيات معالجة المياه الكيميائية والفيزيائية والبيولوجية الحالية لا تقوم بإزالة جميع العناصر الحيوية (النترات والأمونيا والفوسفات) والملوثات الأخرى لإعادة استخدام مياه الصرف الصحي على النحو الأمثل.

اكتسبت التقنيات الحديثة مثل تقنيات الأغشية مؤخراً القبول ويتم استخدامها في على نطاق واسع وفي أنحاء العالم وبحجم محطات كبيرة. يوفر التناضح العكسي معدلات إزالة عالية للعديد من الملوثات مثل المواد الصلبة الذائبة والمعادن الثقيلة والملوثات العضوية والفيروسات والبكتيريا والملوثات الأخرى الذائبة ذات الاستهلاك المنخفض من الطاقة. ومع ذلك، من أجل تطبيق التناضح العكسي بنجاح لمعالجة المياه العادمة، يلزم إجراء معالجة مسبقة مناسبة لتقليل معدلات الانسداد وحدات التحلية ولإطالة عمر الغشاء.

يهدف هذا البحث لتقييم أداء استخدام التناضح العكسي كمعالجة متقدمة لمياه الصرف الصحي الناتجة من محطات المعالجة في غزة ومقارنتها مع المعايير الفلسطينية للاستخدامات غير الشرب مثل الزراعة وإعادة تغذية المياه الجوفية. كما يهدف البحث إلى تقدير التكلفة الإجمالية لتطبيق مثل هذه التقنية.

تم إجراء التجربة على مرتين باستخدام وحدة غشاء التناضح العكسي. في كل تجربة، تم جمع مياه الصرف المعالجة جزئيا من مياه الصرف الصحي من محطة معالجة غزة وتغذيتها إلى مرشح رملي ثم إلى ثلاث مراحل من أغشية الترشيح الدقيقة MFكمعالجة مسبقة ثم إلى وحدة غشاء التناضح العكسي. تم اختبار BOD وTSS وTDS وFC وNO3 وpH وEC ودرجة الحرارة في كل مرحلة من مراحل نظام التجربة.

تظهر النتائج أن التناضح العكسي مع المعالجة المسبقة المرافقة له لديها القدرة على إزالة 100 ٪ من BOD، 92 ٪ من TSS، 100 ٪ من النيترات، 100 ٪ من FC، و 88 ٪ من TDS. علاوة على ذلك، تم إجراء تحليل للتكلفة لاستخدام هذه التقنية واظهرت النتائج أن تكلفة المتر المكعب الواحد من مياه الصرف الصحي المعالجة أقل من 0.9 دولار وتستهلك طاقة اقل من 0.7 كيلو وات بالساعة.

بسم الله الرحمن الرحيم

﴿ رَبِّ أَوْزِعْنِي أَنْ أَشْكُرَ نِعْمَتَكَ الَّتِي أَنْعَمْتَ عَلَيَّ وَعَلَىٰ وَالِدَيَّ وَأَنْ أَعْمَلَ
صَالِحًا تَرْضَاهُ وَأَدْخِلْنِي بِرَحْمَتِكَ فِي عِبَادِكَ الصَّالِحِينَ﴾

[النمل: 19]

"My Lord, enable me to be grateful for Your favor which You have bestowed upon me and upon my parents and to do righteousness of which You approve. And admit me by Your mercy into [the ranks of] Your righteous servants."

(An-Naml – 19)

DEDICATION

- This work mainly dedicates for Allah pleasing
- To my parents for their kindness and support
- To my wife for her encouragement
- To my beloved Kids Moeen & Mira
- To my brothers and sisters
- To all knowledge seekers
- To everyone who search for better life and prosperous future for humankind

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List of Abbreviation & Units

AOP	Advanced Oxidation Process
AWT	Advanced Water Treatment
BOD	Biochemical Oxygen Demand
°C	Degrees Celsius
Cl	Chloride
CMWU	Coastal Municipal Water Utility
COD	Chemical Oxygen Demand
DOC	Dissolved Organic Carbon
dS/m	Decisiemens Per Meter
EC	Electrical Conductivity
FC	Fecal Coliform
GWWTP	Gaza Wastewater Treatment Plant
h	Hour
kW	Kilo Watt
L	Liter
l/c/d	Liter Per Capita Per Day
Lab	Laboratory
m3	Cubic Meter
mm	Millimeter
MCM	Million Cubic Meter
MGD	Million Gallons per Day
MLD	Million Liter per Day
MPN	Most Probable Number
MF	Micro Filtration
MOA	Ministry Of Agriculture (Palestine)
NF	Nano Filtration
NH3	Ammonia
NO3	Nitrate
PPM	Part Per Million
PSI	Palestinian Standards Institute
PWA	Palestinian Water Authority
RO	Reverse Osmosis
SF	Sand Filter
STLV	Short Term Low Volume
TKN	Total Kjeldahl Nitrogen
TS	Total Solid
TWW	Treated Wastewater
UF	Ultrafiltration
UNDP	United Nations Development Programme
WWTPs	Wastewater Treatment Plants
WW	Wastewater

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Chapter 1:
Introduction

CHAPTER 1:
INTRODUCTION

1.1 Background

The Middle East and North Africa (MENA) countries which contains 6.3% of the world's population are considered to be the highest water-scarce countries in the world, sharing only 1.4% of the world's renewable fresh water. These countries use more of its renewable water resources than it receives each year and more water than other countries. (Hamoda et al., 2015)

Gaza Strip is categorized as a semi-arid region and suffers from water scarcity. Water demand in Gaza Strip is growing continuously due to population increase while the water resources are constant or even reducing due to urban development. The demanded amount of water is much more the renewable quantity of water that replenishes the groundwater, which lead to deterioration of the groundwater system in both quantitative and qualitative aspects (Jarboo et al., 2015).

The annual average rainfall differs from (400-200mm) from the north to south respectively. Total abstraction of groundwater in Gaza Strip exceeds 200 MCM year (PWA,2014). Around two thirds of groundwater pumped through more than 10000 wells used for agriculture purpose. 120 MCM annual deficit of water balance, due to increasing of the gap between water demand and water supply, as a result of rapid population growth in this small area. There is a pressing need to protect and conserve fresh water and to use the water of low quality or treated wastewater for non-potable uses. This is mainly because agriculture dominates the Palestinian water consumption with about 50%, while leaving 50% for domestic and industrial purposes (PWA, 2014).

There are five wastewater treatment plants operating in the Gaza Governorates: North Gaza wastewater treatment plant in the north, Gaza wastewater treatment plant in the Gaza city, Wadi Gaza wastewater plant, Khan Younis and Rafah wastewater treatment plants in the south. The existing WWTPs are heavily overloaded as the actual flow far exceeds the design flow. The total effluent of WWTPs is approximately over 50 MCM / year. The Mediterranean Sea acts as the final discarding of fully treated or partially treated wastewater in Gaza strip without any significant reuse (CMWU, 2012).

The reuse of effluent is one of the master solution option being contemplated as a new source of water in counties. Effluent reuse has also become an attractive choice for protecting the ecosystem. In the last decade, there has been an important diversity of water reuse practices, such as green space and crop irrigation, industrial applications, and aquifer replenishment (Bouregba et al., 2016).

Wastewater reuse is the processing to make it reclaimable with definable treatment reliability and to meet the needed effluent quality guidelines standards. Over the last decades, the concept of encouraging effluent reclamation for water reuse to offer a water resource supplement has grown worldwide (Asano,1998). If the quantity of wastewater is reclaimed to a good quality, we can save the groundwater for other purposes. This falls under the principle of sustainability, recycling and reuse of available resources. Besides, reuse of treated effluent in irrigated agriculture would reduce environmental pollution caused by untreated/poorly treated wastewater (Angelakis, A. N, 2001).

Although, the use of reclaimed effluent for agriculture is subject to major concern because of the possible increasing rapidly of social and environmental problem. The public acceptance to use treated wastewater is a critical aspect to ensure the success of any reuse project. Also, wastewater may contain unwanted chemical component and pathogens that create negative environmental and health impacts. As the result, mismanagement of wastewater irrigation would create environmental and health problems to the environment and human beings (Huertas et al., 2008).

Presently, the reuse of reclaimed effluent is very restricted to a few illegal irrigation sites beside the treatment plants, or limited to research activities. The quality of the effluents would nearly meet Class C, PWA- Palestine Standards. Standards for effluent reuse have recently been adopted (PS 742 / 2003). These set conditions on a range of reuse options, aquifer recharge and sea discharge, with associated limit values for physical, chemical and microbiological parameters, although discharge to Wadi is not mentioned. Reclaimed water quality evaluation is required to determine conformity with applicable criteria and standards.

A current typical process for municipal wastewater consists of primary, secondary and tertiary treatments. The resulting effluent is low in turbidity and can be disinfected for discharge purposes. However, this process does not decrease the level of dissolved particles and the water is generally not suitable for discharging into groundwater or un-restricted reusing for agriculture irrigation.

For the time being, membrane technologies such as micro, ultra, nanofiltration, and Reverse osmosis (RO) play an increasingly important role in effluent treatment in wide-ranging municipal wastewater treatment plants. Membrane technology employ a semi-permeable membrane for the elimination of solids and pollutants from wastewater. It has been utilized for many years in desalination of brackish and seawater and was recently applied in the wastewater treatment domain. Membrane technologies are gaining special recognition as alternatives to conventional effluent treatment and as a means of purifying treated effluent for reuse applications (Akther, N., 2015).

The ability of RO membranes to successfully treat wastewater and provide water with quality exceeding the requirement have been confirmed. There has been quick prosperity in RO usage in the reclamation of wastewater all over the world. Compared to other technologies, RO offers low energy consumption with high rate of pollutants and contaminates removal. Meanwhile, the most significant aspect in the design of RO based effluent treatment system is to reduce membrane fouling by selection of suitable and proper pre-treatment process such as Ultrafiltration (UF) or Microfiltration (MF) (Hamoda, 2015).

1.2 Aim and Objectives

The main aim of this study was to assess the performance of Reverse Osmosis in improving the quality of effluent from Gaza wastewater treatment plant.

The specific objectives were:

- To investigate the quality of treated wastewater using RO membranes (preceded by suitable pre-treatment method) as a post treatment in Gaza wastewater treatment plant.

- To estimate the cost of applying RO as a post treatment for Gaza wastewater treatment plants.

1.3 Problem Statement

Freshwater shortage is becoming an increasingly severe problem in Gaza strip. Gaza Strip suffers from lack of water resources. The coastal aquifer is the sole source to meet the fresh water needs of the residents of the Gaza Strip, but it has a limited capacity to meet these needs. It is suffering from sharp and continuous attrition, which is expected to reach a water deficit of 120 MCM per year (PCBS, 2011). In the event of continuing the same policies that were followed during the past years (pumping, the lack of sustainable management), this may lead to acute deterioration of water resources, groundwater may become more saline due to seawater intrusion.

The sewage discharge in the sea seems to be a problem; it is not only contaminating Gaza sea water but also posing health risks for bathers and consumers of seafood. This situation can lead to the spread of pathogens that are multi-drug resistant. Water quality tests performed in late April 2008 by the World Health Organization at 13 points along Gaza's coast found that four sites (Three in Gaza city and one in Rafah city) are polluted with high levels of fecal bacteria. This would indicate that pathogenic organisms within the general population may be being released to the coastal waters, thereby posing health risks to those who bathe in or consume shellfish from contaminated waters (Alafifi, 2006)

Therefore, conventional methods for wastewater treatment are not enough to preserve environment or maintain public health and didn't reach the minimum international treatment standard to use it in agriculture, discharge it in groundwater or even dispose it into sea.

1.4 Thesis structure

This thesis consists of Seven chapters structured and detailed as follows:

Chapter one: Introduction, prefaces for wastewater situation in Gaza Strip and RO, the main objective definition, research importance and methodology

Chapter two: Literature review for the related topics and case studies for similar projects in the world.

Chapter three: Study area, wastewater situation and wastewater treatment plants in Gaza Strip.

Chapter four: Methodology.

Chapter five: Describes the result of experiments

Chapter six: Estimate cost for applying RO in GWWTP

Chapter seven: Defines recommendation and conclusion of the experiment

1.5 Research Importance

The crisis of water scarcity looming on the horizon and threatens the stability and security of the Gaza strip. The crisis will continue and increase with time, if no suitable actions are taken as soon as possible. Reuse of reclaimed wastewater has two major objectives: it improves the environment quality by reducing the level of contaminants load into the receiving water resources or to the Mediterranean Sea, and it conserves water resources by reducing the demand for groundwater abstraction.

The reuse of treated wastewater, particularly in irrigated agriculture because it uses 50% of all water consumption, are the most recommended alternatives for alleviation of the sever water shortage in Palestine. On the other hand, the quality of treated wastewater must meet the international standard for non-potable use and has to gain public and social acceptance which conventional wastewater method of treatment failed to achieve.

1.6 Research Methodology

The methodology followed to achieve the study objectives is summarized as follows:

1- Identify the research problem, research justification, set out the research's aim and objectives.

2- Review previous studies, researches, research papers and journals related to using membrane technologies as wastewater post treatment method.

3- Design experimental set up to investigate the quality of treated wastewater using RO membranes.

4- Estimate the cost of applying RO as a post treatment for Gaza wastewater treatment plant and make a comparison with worldwide similar project.

5- Make final conclusions and recommendations for feasibility of using RO as post treatment for wastewater to meet international standards

Chapter 2:
Literature Review

Chapter 2:
Literature Review

2.1 Background

Water has a priceless value and each drop must be considered in water scarcity Areas. Water-related problems are increasingly known as one of the most actual and serious environmental threats to human kind. Water usage all over the world has tripled since 1950, and one out of every six persons does not have regular access to safe potable water. Lack of access to a safe water supply and sanitation impacts the health of 1.2 billion people every year. (UNICEF, 2000).

The coastal aquifer is the only source of water in the Gaza Strip. The annual recharge volume, equaled to the sustainable yield for the aquifer, is in the range of 55-60 MCM/yr. The Palestinian abstraction from this aquifer in Gaza Strip was about 178 MCM in 2013. The agriculture sector consumes around 88 MCM/year of the entire groundwater pumped through wells (legal and illegal) located overall Gaza Governorates. The remaining 90 MCM/year is used for domestic and industrial water supplies. The water balance record shows a deficit of about 120 MCM/year (PWA 2013).

Many modernistic and conventional approaches, exist globally for efficiency enhancement. These approaches to overcome this shortage rely in the policy of ensuring additional water supply and wastewater reuse plan. Using effluent water could be one of the main choices to improve the water resources in the Gaza Strip as it appears an additional reliable and renewable water source (Afifi, 2000).

2.2 Wastewater Reuse

The phrase “wastewater” mainly means any water that is no longer needed, as no further benefits can be obtained out of it. About 99 percent of wastewater is water, and only one percent is solid wastes. Water reuse is the reclamation of treated wastewater for a advantageous use. It is a "reuse" because the user does not get this water from natural source like surface water or groundwater, it is a consequence of human sanitation and of industrial processes (Metcalf & Eddy, 2003). By waste components reduction from wastewater to an accepted level, treated wastewater can be used safely for several purposes like agricultural, commercial, residential and industrial uses.

The wastewater worth is becoming progressively understood in arid and semi-arid regions and many countries are currently looking forward to improve and expand effluent reuse applications. Effluent reuse also has become increasingly significant in water resource management for both environmental and economic causes. Researchers and scientists, aware of both benefits and risks, are assess it as one of the choices for future generations water demands.

Effluent reuse has primarily a long history of implementation, by quantities, agricultural irrigation is the largest consumer of reclaimed effluent and this is anticipated to increase more, especially in developing countries, another major consumer is for industry particularly for cooling and processing. A second category of reuse is the indirect reuse. Highly reclaimed wastewater can be recharged to groundwater to replenish aquifers. This is an indirect reuse where the reclaimed water will be mixed with the groundwater (Metcalf & Eddy, 2003).

In Palestine, wastewater reuse projects are affected by political, financial, social, institutional, and technical aspects. reclaimed wastewater reuse is still attached to the political issues related Palestinian water rights, since Israel considers reused wastewater as part of Palestinian total freshwater quota (Samhan, 2008).

2.3 Wastewater Characteristics

Treated wastewater quality is the physical, biological, and chemical characteristics of a liquid flowing from a constituent. The constituent of wastewater can be listed as:

- biochemical oxygen demand, total suspended solids and fats, oils and grease (BODs, TSS, FOG)
- pathogens (fecal coliform, viruses)
- nutrients (nitrogen, phosphorus)
- Other chemicals.

2.3.1 Types of BOD

High intensity wastewater is an influent which have *BODs* more than 300 mg/L;

and/or TSS more than 200 mg/L; and/or fats, oils, and grease FOG more than 50 mg/L.

I- Biochemical Oxygen Demand

Biochemical Oxygen Demand is the quantity of dissolved oxygen consumed by microorganisms during the microbial and chemical oxidation of the constituents contained in a wastewater sample during an incubation period at a given temperature. The biochemical oxygen demand represents the oxygen utilized during the oxidation of both carbon and nitrogenous composite.

II- Biochemical Oxygen Demand (BOD5)

Biochemical Oxygen Demand-5days is the amount of dissolved oxygen consumed by microorganisms during the breakdown of organic matter in a wastewater sample during five days incubation period and measured in mg/L at 20°C. It is used as a means to show the amount of organic matter existing in the sample.

III- Chemical Oxygen Demand (COD)

Chemical Oxygen Demand is a measure of the quantity of organic matter oxidized by a strong chemical oxidant. COD is used to measure organic matter in industrial, commercial and municipal effluent that could carry composite toxic to biologic life where the *BOD5* test wouldn't work. The COD test can generally be done within 150 minutes and the COD levels is always greater than levels of BOD5 for the same wastewater sample.

In most cases, the *BOD5* concentration can be anticipated when the *COD/BOD5* relationship is known for a specific facility and the COD concentration of a effluent can be measured.

2.3.2 Types of microbiological

I- Pathogens

The most crucial constituent, in terms of what must be eliminated from effluent, is pathogens. Pathogens are organisms that cause diseases such as viruses, protozoa, parasites, and bacteria. Pathogens could be found in any type of wastewater. Any human or environment contact with this water results in potential risk. Because of their ability in spreading disease, pathogens in wastewater make reclamation a public health concern.

II- Fecal Coliforms (FC)

Several of the organisms found in effluent can cause disease while others are harmless. It is almost impossible to identify all the pathogenic microorganisms in effluent .Fecal coliform bacteria, which is usually exist in digestive systems of warm blooded animals including human being, is used to indicate either fecal contamination from sewage or the level of disinfection generally measured as number of colonies/100mL or Most Probable Number (MPN) .It is the most popular test for pathogens because it is a comparatively simple and low-priced test.

2.4 Treatment Methods

Methods of reclamation in which the implementation of physical forces dominate are known as operations. Methods of treatment in which the level of pollutants is done by chemical or biological reactions are known as processes. Nowadays, operations and processes are put together to provide several levels of treatment known as preliminary, primary, advanced primary, secondary, tertiary and advanced (Quandary) treatment as shown in (Table 2.1).

In preliminary treatment, to avoid damage for equipment the total solids such as big objects, sand and grit must be eliminated. In primary treatment, a physical operation commonly sedimentation, is used to eliminate the floating and settleable components in wastewater. In order to improve the elimination of suspended and dissolved solids chemicals can be added. In secondary treatment, biological and chemical processes are used to eliminate major of the organic components. In tertiary treatment, others further groups of operations and processes are used to remove remaining suspended solids and other components that are not reduced by the previous conventional secondary treatment. In Quandary (Advanced) treatment, membrane technology like UF/RO are able to remove all types of pollutants that's remains from tertiary treatment and able to produce potable water quality. (Metcalf & Eddy,2003)

Table (2.1): Levels of wastewater treatments

Treatment Level	Description
Preliminary	Removal of wastewater constituent such as rags, grits, and grace which may cause problems with the treatment operations.
Primary	Removal of part of the suspended solids and organic matters
Advanced Primary	Increase the portion of elimination of suspended solids and organic matters by chemical addition or filtration.
Secondary	Elimination of biodegradable organic matter, dissolved or suspended solids
Secondary with nutrient removal	Elimination of biodegradable organics, suspended solids, and nutrients such as nitrogen, phosphorus, or both.
Tertiary	Elimination of residual suspended solids and nutrient by granular medium filtration or micro screens. Also, it may contain disinfection.
Quaternary (Advanced)	Removal of all types of pollutants and contaminants in water using membrane technology which is producing a quality comparable to drinking water

In order to reuse effluent, it is vital to treat it to meet specific quality standard for the specific needs and to insure the public safety. Wastewater reclamation processes can be categorized into the following three:

I. **Physical process**: Include processes where no major chemical or biological changes are occurred and physical phenomena are employed to treat the wastewater such as:

coarse screening process to remove larger particles, sedimentation process which is holding wastewater for certain period of time to settle solids by gravity and the greases or oils will flow and will be skimmed, adsorption process that uses activated carbon to remove organic and ion exchange process that uses to exchange certain ions for others, filtration process which is allow water to pass throw filters voids and the blocks solids and finally equalization process which is hold and mix widely varying amounts of wastewater and gradually release them to eliminating shocks to the treatment plant and to make wastewater more uniform

II. Chemical process: There is a lot of chemical process that is used in effluent reclamation operations such as: Neutralization process which is comprise of the adding acid or base to adjust pH levels to reach neutrality, Coagulation process which is comprise of addition chemical through a chemical reaction, forms a component which is impossible to solve and that make it easy to remove from the wastewater.

III. Biological process: Which uses bacteria or other organisms in the biochemical disintegration of effluent to stabilize components. More microorganisms, or sludges, are created and a part of the pollutants is transferred to carbon dioxide, water and other component. In general, according to availability of dissolved oxygen biological treatment methods can be split into aerobic and anaerobic methods.

The purpose of wastewater treatment is generally to remove from the wastewater enough pollutants and solids (organic and inorganic) in order to make the treated wastewater suitable for non-portable uses or even for discharging in ecosystem and the removed solid can be collected as sludge. Final treatment may also be necessary to rule odors, to retard biological activity, and demolish pathogenic organisms.

2.5 Quaternary (Advanced) treatment using membrane processes

2.5.1 Introduction

The level of treatment supplied to municipal effluent will mostly be according to the needed standards for reclaimed wastewater set by the local or international regulatory organizations when the wastewater is to be reused for different purposes, or to be discharged into ecosystem. So, several treatment facilities provide the tertiary-treated effluent with quaternary treatment using membrane processes to produce an effluent appropriate for all kind of water reuse application.

Membrane technology uses a semipermeable membrane to separate of suspended, dissolved solids from water. It has been applied for considerable years in brackish and seawaters desalination and recently was adopted in the wastewater treatment field.

Membrane technologies such as micro, ultra, nanofiltration, and RO are gaining more attention, receiving special recognition as alternates to conventional wastewater treatment and increasing the treated wastewater reuse applications.

There has been a rapid growth in the using of reverse osmosis (RO) in purification of wastewater. Nowadays, there are a lot of large-scale municipal wastewater plants in the world in operation or under construction. Comparing to others technologies, the main motivation for this is the low energy consumption of RO and the high rate of pollutant and contaminant removal. Meanwhile, the most important aspect for the RO wastewater treatment system design is to use a proper pretreatment method such as ultrafiltration (UF) or conventional pretreatment to remove suspended solids in order to minimize membrane fouling to extend membrane life.

2.5.2 Pre-treatment for Reverse osmosis

Traditional wastewater treatment is often comprised of a primary settling phase, followed by biological treatment and reclamation of the biological material in a secondary settling phase. After the secondary settling phase. Wastewater effluent is usually rich in organic carbon, phosphorus and nitrogen. Combined with high water temperatures, this can lead to bio fouling on the reversed osmosis (RO) membranes (Shang, et al. 2011).

Nowadays pretreatment stage is the most important issue in the implementation of RO based desalination technology. Undesirable Fouling of the RO membranes in the plant could lead to damage the membranes and reduce its life also frequently cleaning process could damage the membranes and should be done as little as possible.

Sand filter filtration is conventionally applied as pretreatment process for all kind of reverse osmosis operation. however, recently microfiltration (MF) or ultrafiltration (UF) with polymeric membranes are used as pretreatment for RO to remove these substances from the WWTP effluent which called as dual membrane process.

I. Filtration with sand filter

Sand media filtration has been used since long time to treat water and wastewater. Filtration is defined as an interaction among solute particles and a filtering component ،contaminants particles are separated from the solution when they become tied to the media or to already caught particles, using of sand filtration is popular for potable water and wastewater treatment.

AWWA, 2001, Torrens, 2009, Anderson,1985 and Woelkers, 2006 reported that the effective selection of a filter media as sand filter to produce adequate required contaminant elimination performance be conditional on the appropriate selection of the filters depth, type of sand, sand size distribution, quality of influent and effluent water, the filtration rate, and dosing system and stopping period duration, all influenced the performance and treatment efficiency of the filters.

Granular media with too coarse reduce the retention time to a degree that sufficient biological disintegration is not impossible to achieve. Coarser media have larger pore opening that have high flux rates but let larger suspended particles passes. While, granular media with too fine media lead to early filter clogging which will reduce the quantity of water that may be passed. A very fine sand, or other fine material filter has tiny pore opening with slow flux rates and removes out smaller TSS particles (Urbonas, 2003).

Comprehensive filtration performance is controlled and affected by many aspects such as the required treatment rate, the influent water quality and the physical characteristics of the used material (type, depth, size distribution, and hydraulic loading rate)

Generally, filter performance is evaluated by the following parameters: the effluent of water quality (turbidity, BOD, SS, TDS), water production volume and head-loss (backwash time or material replacement if no backwash is used). (Clark, 2007).

II. Microfiltration or Ultrafiltration process

The MF and UF membrane equipment were tested in a system for long operation as a pretreatment substitutional to sand filtration for RO plants. Both MF and UF installations, shows a good potential for a dependable long operation. This proof that MF/UF application to RO pretreatment in better choice for future plants.

The conventional pretreatment for RO plants based on sand filters offers good results for the low contaminated effluent. However, the conventional pretreatment is known as rather cumbersome one which is cause the variability of the filtrate quality, causing the membrane fouling. Using MF and UF membranes as an alternative for conventional RO pretreatment could save the large area of the sand filters and the chemicals used in pretreatment. On other hand using MF and UF can offer better effluent quality to the RO installation that should reduce biological fouling, extend lifetime and enhance performance of the RO membranes (Feigin et al., 2012)

2.5.3 Reverse osmosis

Reverse Osmosis (RO) is a process that employ semi-permeable spiral wound membranes to remove and separate solute solids and other contaminants like pyrogens, color, submicron colloidal matter, bacteria and viruses from solution which is wastewater. Wastewater is transferred under high pressure across the semi permeable membrane, where water penetrate the tiny small pores of the membrane and wastewater desalinated to water called permeate water. The solids and contaminant, which was rejected by membrane, are gathered and concentrated in the reject stream and will be drained is called brine or concentrate water (Shannon et al., 2010)

RO membranes usually are made of cellulose acetate, polyamides and other polymers materials. The membrane consists of hollow fiber, spiral-wound usually used for wastewater desalination, these membranes are semi-permeable and block the solid ions while allow the water molecules penetrate. Generally, type of membrane depends on the influent water quality and the operation parameters of the plant. Membrane based seawater purification and wastewater reuse are exceedingly considered as promising solutions to increase water supply and mitigate water scarcity (Judd, et al., 2003)

I. Reverse osmosis for wastewater

There is a growing use of reverse osmosis (RO) in the wastewater purification. Comparing with other techniques, the major motives for this technology are the low energy consumption and the high percentage of pollutant elimination. The dependability of the RO treatment plants is very high and improves with time which gives researches and developers confidence of this technology.

RO treatment of wastewater beginning was in the late 1970s with small plants, like Orange County Water region plant. The experience obtained from the many years of operation of existing plants has been a fundamental factor to the growth and augmentation of uses of this technology. Currently, numerous of mega-sized wastewater RO based plant are now in operation or under construction all over the world.

A standard conventional process for municipal wastewater composed of primary, secondary and tertiary treatments. This treatment is not necessary enough in reduction all contaminant and pollutant from wastewater to make it generally usable for all kind of uses and without restrictions. So, membrane technology like RO can complete the job and can offer quality by far better than conventional methods. But when tertiary effluent from a conventional treatment method is pumped to a RO system, it is popular to have all kinds of biofouling as colloidal, biological, scaling and organic fouling.

The layer of biofouling will cover pores and block water flux across the membranes. Early trials to use RO membranes in treating wastewater faced a quick fouling and clogging problem which need cleaning frequently (every 3 days) and this leads to shorten the life of membrane and increase the operation cost.

In the last decade, breakthrough happened in researches of using RO membrane in wastewater treatment with high rates of operation stability, acceptable lifetime of membrane with affordable cost. This work was mostly the result of experiment at the water facility in Orange district, USA, and the plant in Bedok Singapore.

Reverse osmosis (RO) membranes have been demonstrated to notably minimize total dissolved solids, organic pollutants, microorganisms, and other dissolved pollutants. Experience from largescale commercial membrane wastewater reclamation plants has shown that crucial design aspects must be followed to avoid quick membrane fouling, and thus minimize elevated maintenance costs for system. Current best applications contain the usage of other membrane-based technology as ultrafiltration or microfiltration membranes to remove colloidal debris, maintain a chloramine residual to avoid bio-growth, choose suitable anti-scaling chemicals, reduce RO recovery percentages to prevent membrane scaling, and use membranes which reduce biofouling. Select traditional polyamide and reduce fouling membranes have been used successfully at plants such as the West Basin Wastewater treatment plant in California or the Bedok and Kranji plants in Singapore. These large-scale plants give the basis for implementation in even larger plants, and big contribution to the water supply in water-scarce and arid countries.

A lot of researches have been carried out on the rejection of organic contaminants by RO membranes, and these researches have specified some of characteristic linked with contaminants rejection. (Sourirajan,1970 & Matsuura,1985) have assembled rejection and flow data of cellulose acetate membranes for a lot of organic particles, including many organic contaminants. They discovered that organic rejection can very diverge from (0% to 100%) controlled by the physical aspects of the pollutant (charge, size, polarity, etc.) and operating situation (Influent pH, system pressure, etc.). In previous research, (Anderson, 1972) reviewed some of the aspects affecting separation of various organics pollutant such as (acetone, urea, phenol, and dichlorophenol) by cellulose acetate membranes. Separation of solids highly varied for the different wastewater, and separation of ionizable organics that highly dependent on degree of disconnection. No ionized matter was found to be highly absorbed by the membranes and showed poor separation.

Duvel and Helfgott, 1975 also discovered organic pollutant elimination differ with molecular size and dividing; they assumed organic rejection was also a function of the matter's chance to form hydrogen bonds with the membrane (Duvel Jr& Helfgott, T, 1975).

Edwards and Schubert, 1974 reported elimination results of herbicides and pesticides with RO membranes. They discovered that herbicide separations were up to 51%. They listed that that dissolved particles adsorption can happen on the cellulose acetate membranes (Edwards, V. & Schubert, P, 1974). Fang and Chian, 1976 performed research on the elimination of multi polar organic matters with several functional sets using cellulose acetate and various other kinds of membranes. This research reviewed that the organic separation differs highly not only with dissolved particles type but also with membrane type. Also, they reported high elimination over 99% for various pesticides with cellulose acetate and a compound membrane; Although, notable adsorption of the pesticides on the membranes was occurred. (Shuckrow, 1981) as well reviewed cellulose acetate separation of various types of organics, rejections were low to moderate (10% for methylene chloride, 73% for acenaphthene) (Shuckrow, A. et al., 1981).

Many researches have made comparison between organic separation of cellulose acetate and separation with other types of membranes, and a large number of these have specified that aromatic polyamide and compounds membranes generally have organic separation better than those of cellulose acetate membranes, (Kurihara, 1981) reviewed various organic separation of the Toray compounds membrane (polyfuran), generality separations were high, (97% for acetone) and (99% for phenol).

(Koyamal,1982 and Koyama ,1984) listed rejections results for various polar organic dissolved particles (alcohols, phenols, carboxylic acids, amines, and ketones) and several phenolic derivatives for a composite membrane. They discovered that the major aspect influencing separation (molecular weight, molecular branching, polarity, and degree of detachment for ionizable component). (Lynch, 1984) make comparison between cellulose acetate and thin-film, compounds membrane a bonded aromatic polyamide) rejections with a various of organic contaminants. The composite membrane separation (more than 90% of the organics) and water flows were extraordinarily better than the cellulose acetate membrane; although, adsorption of number of the organics on the membranes was listed.

(Light, 1981) indicated dilute solutions of polynuclear aromatic hydrocarbons (PAHs), aromatic amines, and nitrosamines and found separations of these components was more than 99% for polyamide membranes. (Rickabaugh,1986) also studied polyamide membrane separations of chlorinated hydrocarbons more than 95% which is better than cellulose acetate Membranes separation.

Reverse osmosis is best solution for pollutant removal from effluent of biological or other conventional municipal reclamation that was failed to remove. RO is able to remove dissolved solids which can't be eliminated by conventional municipal treatment operation. Besides, RO membranes can help in reduce microorganism, odors, colors, and nitrate levels. Although, comprehensive pretreatment and periodical cleaning are usually necessary to preserve acceptable membrane water flows.

(Tsuge and Mori, 1977) demonstrated that tubular RO membranes with a suitable pretreatment system can eliminated inorganics and organics pollutants from municipal treatment plants wastewater and made effluent meets potable water standards.

(Stafstrom ,1982) reviewed over a three years municipal wastewater reclamation using tubular cellulose acetate RO membranes. TDS removal was 81%, and TOC removal was 94%, making the treated water appropriate for reuse. Although, pretreatment process was essential to insure good water flow rates.

(Richardson and Argo, 1977, Allen and Elser, 1979, Argo and Montes, 1979, Nussbaum and Argo, 1984), and Reinhard, 1986) have reviewed water factory municipal wastewater reclamation in Orange country, USA which is large scale plant. The plant influent was from of effluent of secondary treatment, and the process was consisting of a various of treatment processes, including RO membranes (various different types) with ability to produce five MGD of highly treated effluent. The process minimizes pollutants to levels that allowed effluent to be recharged to groundwater safely to replenish aquifer and to make barrier for seawater intrusion.

(Suzuki and Minami,1991) listed researches on using various RO membranes to treat secondary treated wastewater that contain several salts and dissolved organic materials. TDS removal was up to 99% and TOC removal was up to 90% were discovered, and fecal coliform collection removal was more than 99.9%. Decreasing water flow over time were noticed but could be partially reinstate by frequent cleaning.

Membrane based technology have become attractive solution to take the place of conventional wastewater treatment because of low costs, high efficiencies and low chemical consumption. Depending on water, composition and type of pollutants need to be removed, Ultra-filtration, Nano filtration or reverse osmosis techniques could be adapted to wastewater treatment to improve quality of wastewater and produce effluents for agricultural, industrial and domestic applications.

2.6 Potential of Wastewater Reuse Applications

Usage of reclaimed wastewater depends on various aspects; supply, demand, treatment needs, storing and distributing constructions. Besides, effluent reuse is oftentimes linked with ecological and health hazards concerns. Consequently, the acceptance of replacement other water resources for irrigation is extremely depends on acceptance of the health hazards and ecological impacts involved. In the following, the main kinds of reuse will be listed:

1- Agricultural Use

The need for amount of treated wastewater for irrigation differ monthly through the year due to climatic condition. Also, seasonal variation such as rainfall amount, temperature and other factors such as kind of crop, plant growth phase, and irrigation system.

The provider of treated effluent should take in consideration these seasonal requirements and the variation of the influent quality, to meet the demands for agriculture. To evaluate the feasibility of reuse, the treated wastewater provider must be able to rationally assess agriculture demand and influent supplies.

The main concern in using treated wastewater in agriculture are salinity, sodium, trace elements, excessive and chlorine residual. Sensitivity is basically a function of an individual tolerance for plant to component encountered in the roots zone or deposited on the soil. Treated wastewater more likely to have more concentrations of these component than the natural water sources. The kinds and component concentricity in treated effluent depend on the water supply, the wastewater flow if it is domestic or industrial, amount and composition of infiltration in the sewage system, the effluent reclamation processes, and the kinds of storing constructions. In major cases, the treated wastewater has acceptable quality if it is from municipal sources.

2- **Groundwater Recharge**

The soil ability for filtration and decomposition organic material make the groundwater recharging one of the best reclaimed wastewater reuses options, thus offering extra treating for the effluent in situ and further treating dependability to the comprehensive effluent management system.

The treatment attained in the subsurface environment may cancel the need for sophisticated wastewater treatment plants, depending on recharge technique, hydro geological conditions, user's needs, and other aspects. In some cases, the treated wastewater and groundwater mixed and can't be distinguished. Groundwater recharge helps provide identity losing between treated wastewater and groundwater. Thus, this can widen the variety of using the reclaimed wastewater and make the reuse more psychological accepted. Generally, the purposes of groundwater recharge using reclaimed water include:

- Prevent seawater intrusion in coastal aquifers.
- Provide advanced treatment for future reuse.
- Replenish groundwater aquifer for potable or non-potable uses.
- Offers storage of reclaimed water.

However, there are clear advantages linked with groundwater recharging, there are potential disadvantages to consider (Oaksford, 1985):

- Covering large land zones for operation and maintenance.
- Energy for well recharging may be expensive.
- Recharge may rise the probability of contaminating aquifer.
- May lead to liability and other legal problems.
- Slow movement of groundwater can't meet the sudden increase of demand.

3- Industrial Reuse

Industrial reuse represents an important possible market for reclaimed water in all over the world. Reclaimed water is perfect for many industries where processes do not need potable water quality. Treated wastewater for industrial reuse may be obtain from in plant recycling of industrial wastewaters or municipal water reclamation plant. Recycling within an industrial plant is usually a fundamental part of the industrial process and must be developed on individual basis. Industries, reclaim and reuse their effluent either to maintain water or to meet or avoid strict regulatory standards for wastewater disposals.

2.7 Wastewater Reuse in Agriculture

Like arid and semi-arid regions, use of reclaimed effluent in agriculture is gaining more interest in evolving strategies for planning of Palestinian water resources. Wastewater effluent is the most readily available to offers a partial resolution to the water scarcity problem, the agriculture strip is the second main user of groundwater in the Gaza Strip.

Agricultural irrigation will play a remarkable part in the sustainability of crop production to feed the future generations. Reclaimed wastewater is progressively used for irrigating orchards and fodder crops in Gaza Strip and applied successfully in the neighboring countries. Future of reclaimed effluent reuse sound to be promising in the Gaza Strip.

The anticipated quantities of treated effluent to be used for irrigated agriculture will gradually growth on the next two decades saving more than 50% of groundwater required for agriculture. However, the use of treated effluent for agriculture is source of main anxiety because of the possible sanitary and ecological risks, the bad quality of wastewater may pose fundamental health hazards for the farmers and consumers of those agricultural crops. The WHO has been working to update the guideline standards for reclaimed wastewater reuse in agriculture.

However, reuse of reclaimed, high quality treated effluent for agricultural irrigation is important not only to protects public health but also consider a best preservation plan to reduce the consumption of restricted potable water for agriculture and to minimize fertilizer costs in the agricultural strip of low income territories (Zurita & White, 2014).

AHT GROUP AG, 2009, reported that wastewater reuse for agricultural irrigation involves three main challenges:

1. Quality requirements: To limit all types of negative effects on human sanitary and the environment. This would require suitable treatment of water to be reused and the implementation of secure irrigation techniques.

2. Seasonal demand: Wastewater is generated all the time, but irrigation is only required seasonally, consequently proper storage facilities would be needed.

3 .Location of production: The greatest amount of wastewater is produced in large cities, while agricultural areas are generally located in remote rural districts. As a result, long distance transport networks and pumping would be necessary.

Also, reclaimed wastewater reuse faces technical, legal, institutional and socioeconomic challenges which can be defeated through participatory approaches in which farmers show their perspective and worries for successful application of reclaimed wastewater reuse schemes. (Mizyed, 2013).

Until recent times, it is reported that farmworkers in Gaza are disagreed the reuse of treated effluent, but now a lot of recent studies, suggest that the farmers in Gaza are willing to use reclaimed effluent for irrigating agriculture if there is high-quality wastewater treatment.

According to (NJDEP, 2005), the two mostly common types of water irrigation are:

• **Restricted Irrigation**

Use of bad quality effluents in restricted areas and for particular crops, limitations are decided according to the type of soil, the closeness of the irrigated area to a groundwater aquifer, irrigation techniques, crop harvesting method, and fertilizer usage rate. It is easy and cheap so farmers must be trained to handle the bad-quality effluent.

Unrestricted Irrigation

Use of high quality effluents, as an alternative of potable water, to irrigate all crops (including vegetables) on all types of soil, without restrictions and without exposing human health or environment to risk.

2.7.1 Impact of Wastewater Reuse in Agriculture

Using reclaimed effluent in agriculture is considered as a preferable practice for environment than dispose it in the surface water or groundwater. Consequently, mismanagement of effluent irrigation could lead to problems to both of environment and human being health. Given these risk and benefits, countries is always looking forward to enhance treated wastewater reuse in agriculture by minimize the risks for public health and ecosystem, and maximize the benefits.

I. Benefits of effluent reuse in agriculture

Proper planning, executing and managing for treated effluent irrigation system is very important to get various advantages for agriculture, water resource and environment aspects.

- **Agricultural benefits**

  Agricultural benefits may include: more dependable and less irrigation water cost, more crop yield and better in quality because nutrients in wastewater, more urban agricultural production which contribute in better food security, more employment for generations, and increase income for urban farmers (Jimenez et al., 2010).

- **Water resources management benefits**

  Water resources management may include: extra drought resistant water source, with lower cost than desalination or expanding and enhancing existing resources, additional local source of water, implication of effluent in the wider water resources management, and more integrated water resources management (Jimenez et al., 2010).

- **Environmental benefits**

  Environmental benefits may include: avoiding surface water contamination that could happen if effluent was not used but discharged into surface water, and avoiding a lot of environmental contaminant problems, such as dissolved oxygen reduction, foams, and fish death. Preservation and the rationalistic usage of freshwater resources, particularly in waterless and water-poor zones, freshwater for domestic's demand, wastewater for agricultural use; minimize the needs for chemical fertilizers, which associated with lowering in energy expenses and industrial contamination elsewhere; soil preservation and land erosion preventing; and desert reclamation, through irrigation and fertilization of tree belts (Mara & Cairncross, 1989).

II. Risks of effluent reuse in agriculture

- **Microbial risks to public health:**

  In areas with low and medium income, the biggest risks to public health is from pathogens which is carried in municipal effluent, like bacteria, viruses, protozoa and helminths. Epidemiological researches performed over the preceding forty years have related the employment of non-treated or partially treated effluent without any control for eatable crop irrigation to the spread of diseases to farmworkers and crop consumers. Real dangers of using non-treated effluent for agriculture include the increased spread of helminths illness as ascariasis and hookworm to farmworkers and eaters of raw vegetables, along with bacterial and viral illnesses as diarrhea, typhoid, and cholera. (Shuval & Mara, 1986).

- **Chemical risks to public health:**

  Chemical risks are more dangerous in developed countries where industrial effluents could be disposed to sewage system and pollute municipal effluent. Chemical hazards to public health may be resulted by heavy metals such as cadmium, lead, and mercury; and by other organic component such as insecticide. Besides, there is also concerns from the existence of anthropogenic chemical compounds that is hard to figure its effects on public health in the long-term period such as pharmaceuticals, hormones, antibiotics, and personal care products (Bhandari et al., 2009).

- **Risks to crops**

  The inappropriate effluent quality can reduce crop yields which is major concern. for example, if the effluent is very saline and have large amount of industrial toxicant, or other contaminants. Danger to crops health are decrease if there is small amount of industrial wastes in the effluents, generally, five parameters must be noticed during the irrigation period: EC, SAR, B, TN, and pH (Westcot D.W., 1997).

- **Environmental risks**

  Soil and groundwater contamination are the major danger of utilizing reclaimed effluent in irrigation; the pathogenically contamination of groundwater is a minimal danger because soils will reject microorganisms in the top layers of the soil except in some rare hydro-geological cases.

Chemical hazards include, nitrates in groundwater from effluent irrigation, soil and aquifers salinity, and changing in soil structure. Setting and controlling the efficient industrial wastewater pretreatment is the very important to control the various types of chemical risks that may affect human being and environment (BGS, 2001).

III. Economics of Reclaimed Wastewater Irrigation

The main important factor to take when reviewing the feasibility of reusing treated effluent is the economic and financial viability. The cost effectiveness of a reuse project depends on the amount of treated water used; where the more water used, the more the cost-effective the project (Urkiaga, 2008).

The evaluation process proposes that cost benefit analysis must merge socioeconomic, health and environmental effects of effluent reuse in agriculture, for appropriate evaluation. When wastewater reuse assessment projects, the first method is to group all benefits into two categories, direct and indirect benefits.

For the first, increased crop production, savings on fertilizer costs and on water supply beside offering job opportunities. For the second they are minimized environmental damages, controlled soil erosion and protection of groundwater which reduce waste and improves water preservation (Al-Dadah, 2008).

Water reclamation and reuse is technically feasible but oftentimes it is not a inexpensive choice. The infrastructural requirements are generally high, in particular because of the requirement to build and/or adjust the distribution system (Bixio, 2008).

2.7.2 Public Acceptance

One of the main crucial procedure in any reuse scheme is protecting the public health, particularly that of users and consumers. Consequently, it is main significant to remove any infectious factors or pathogenic microorganisms that may be carried in the effluent. For some reuse implementation, such as irrigating of non-food crops, secondary treatment may be accepted. For different implementation, additional disinfection, by such technique as chlorination or ozonation, could be needful.

The essential prerequisite for wastewater reclamation is that implementation will not lead to inadmissible human health hazards. Non-treated effluent constitutes an earnest danger of water-borne illness, such as cholera, typhoid, dysentery, plague and helminthiasis. With medicinal progression, and human health relations between non-treated effluent and illness have become better comprehend, and measures to reduce exposing to such pathogenic organisms have been presented. Some of the main microorganisms that are existing in untreated effluent are summed up in Table (2.2). In addition, these raw effluents could hold chemical matters that are dangerous to public health and the ecosystem.

Table (2.2): Some of pathogenic organisms linked with raw wastewater

Salmonella, Legionellaceae , Vibrio cholerae	Waterborne bacteria
Giardia lamblia, Cryptosporidium	Protozoa
Ancylostoma (hookworm) , Ascaris, Toxocara, Taenia (tapeworm)	Helminths
Enteroviruses , Hepatitis A virus, Rotaviruses	Viruses

Whereas effluent reuse has essential advantages, a compromise among the advantages and possibility health hazards of implementation should be assess carefully. These hazards can be reduced by appropriate treatment, disinfection, and controlled use of treated wastewater. If sufficient measures to reduce risk can't be performed continually, effluent reuse shouldn’t be accepted.

Effluent reclaim has been experienced for different purposes in several zones of the globe. In most situation, disinfection is fundamental stage before to effluent reuse to reduce ecological and health hazards. The goal of disinfection is to eliminate or deactivate pathogenic organisms from effluent. Usually, disinfection is performed by powerful oxidizers such as chlorine, ozone and bromine, however they don’t deactivate helminths eggs .

The planned implementation for reused effluent effect public acceptability. For example, the use of treated effluent for drinking water or for food preparation experience most objection, while employ for irrigating recreational parks and golf courses gain the minimum public opposition (Asano, 1998). Also, public understanding of the environmental credentials of disinfection techniques for effluent reuse may also impact technology chosen.

2.7.3 Social Acceptance

It needs particular public awareness plan: a better concentrate on inter sectored and multi-disciplined methods and a necessity to realize the goal priorities for the group, knowledge and practice toward particular behaviors and restrains aspects. Behavior with respect to effluent reuse practices include at the community level changing practices of a wide domain of their current practices. In order to maintain the change in these, it is essential not only to extend knowledge and skills to people participatory in water reuse, and to enhance and monitor their behavior locally, but also to originate regional and national systems of supply and maintenance of materials and equipment (Afifi, 2006).

2.8 Regulations and Standards of Treated Wastewater

There are no joint rules of effluent reuse in the world because of different climatological, geological and geographical situations, water resources, kinds of crops and soils, economic and social factors, and country policies towards using reclaimed wastewater for irrigation. Some agencies have founded reuse guidelines as WHO, FAO, USEPA (United States Environmental Protection Agency), etc. Most of the regions now have founded their own standards from the guidance set by FAO, WHO, etc. (EPA, 2004).

2.8.1 WHO guidelines

To protect human health and environment, WHO start developing guidelines for effluent reuse in agricultural irrigation from 1973. After a comprehensive analysis of epidemiological researches and other studies, these standards were modified in 1989. The latest revision was in 2006. These guidelines have been very helpful, and a lot of countries have followed them.

The main characteristics of WHO guidelines for reclaimed effluent reuse in agricultural irrigation are as follows:

- Reclaimed effluent is considered as a safe resource to be used
- The guidelines aim to protect from infection in exposed populations (consumers, farmers).
- Fecal coliforms are utilized as pollution indicators.
- Measures including fine reuse management practice are suggested beside effluent quality target; limitations on irrigated crops; chosen of irrigating techniques that increase health protection, and monitoring of fine personal hygiene (WHO, 1989).

WHO guidelines are listed in table (2.3.)

Table (2.3): WHO guidelines for using treated effluent in irrigation

Category	Reuse conditions	Exposed Group	Fecal coliforms (MPN1/100 ml)	Effluent treatment anticipated to attain the required micro-biological guideline
A	Irrigation of crops probably to be consumed uncooked, sports fields, public parks	Farmers, Users, public	≤ 1000	A series of stabilization ponds designed to attain micro-biological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees	Farmers	≤ 1	Retention in stabilization ponds for 8–10 days or equivalent helminths and fecal coliform elimination
C	Localized irrigation of crops in category B if exposure to workers and the public does not occur	None	Not applicable	Pretreatment as essential by irrigation technology but not less than primary sedimentation

2.8.2 Palestinian standards

For many years, Palestine didn't have any particular effluent reuse regulations or guidelines. References were generally made to the WHO guidelines or to the neighboring countries, standards (Egypt, Jordan).

Recently in Palestine, there is a Palestinian Standard (PS) for the reclaimed effluent (PS-742-2003) which has been established by the Palestinian Ministry of the environment and authorized by the Palestinian Standards Institute, after the establishment of Palestinian law in 1999): "The Ministry (MENA), in organization with the competent organization, shall set standards and rules for gathering, treating, reusing, or disposal effluent and storm water in a right way, which comply with the conservation of the environment and public health" (EQA, 1999).

The Palestinian standards developed in 2003 have general criteria for the reclaimed wastewater reuse in agriculture:

- The reclaimed effluent must meet the particular standards that differ depending on the usage planning.
- When reclaimed wastewater is used for irrigating cooked vegetables, fruit trees, and fodder crops, irrigating must be stopped 14 days before gathering the crops. Fallen crops must be disposed.
- The reverse effect of some reclaimed effluent quality characteristics on the soil parameters and on some crops.
- Avoid using of sprinkler for irrigation.
- Avoid using of reclaimed wastewater in the irrigating vegetables and other crops that may be consumed raw such as tomato, mint, carrots, cucumber, lettuce, or parsley.
- Closed piped or lined channels must be used for carriage of reclaimed wastewater when permeability of soil is high, which can affect groundwater and surface water that could be used for drinking objects.
- Avoid mixing dilution of reclaimed effluent with clean water at the treatment plants in order to meet the required standards (EQA, 2003).

Palestinian standards for effluent reuse have been adopted which set exacting and complex requirements. In addition to many criteria and a multiple barrier approach to health protection, the standards prohibit the use of effluent on crops eaten uncooked, regardless of the extent of treatment.

Four classes of effluent quality are recognized (table 2.4), classified by BOD, TSS and Fecal coliform concentrations. For each effluent class, a number of additional barriers (table 2.5) are required for reuse, the number of barriers required (from a list of eleven) depending on the type of crop (18 crop types are listed). For Class A effluent, no additional barriers are required and Class D requires up to four barriers depending on crop type. Vegetables are specifically excluded. Furthermore, limit values are given for an additional 35 parameters for eight categories of reuse and disposal.

Table (2.4): Classification of wastewater quality (PS 742/2003)

Class	Quality	BOD (mg/l)	TSS (mg/l)	Faecal coliform (MPN1/100 ml)
A	High	20	30	200
B	Good	20	30	1,000
C	Medium	40	50	1,000
D	Low	60	90	1,000

Table (2.5): Recommended PSI effluent standards (PS742/ 2003)

Criteria	Restricted Use1	Unrestricted Use2
BOD (Mg/l)	10-20	10-20
TSS (Mg/l)	15-20	15-20
Total-N (Mg/l)	10-15	10-15
F. coliforms	Less than 200	Less than 1000

Criteria	Restricted Use1	Unrestricted Use2
Helminthes eggs	Less than 1	Less than 1
Intestinal nematoda	Less than 1 ova per liter	Less than 0.1 ova per liter

1. Restricted Use: Cereal crops, industrial crops, fodder crops, crops normally eaten cooked and trees, etc.

2. Unrestricted Use: Crops normally consumed uncooked (vegetables), sport fields, and parks.

Table (2.6): Criteria recommended by PSI for crops (PS742/ 2003)

Parameter	Citrus	Olives	Almonds	Alfalfa
BOD (mg/l)	45	45	45	45
COD (mg/l)	150	150	150	150
TSS (mg/l)	40	40	40	40
TDS (mg/l)	1500	1500	1500	1500
Cl (mg/l)	400	600	400	400
E. Coli (MPN/100 ml)	1000	1000	1000	1000
Pathogens	None	None	None	None

2.9 Limitation of Wastewater Reuse in Gaza

Reclaimed effluent reuse has to overcome diverse obstacles. Upcoming reuse scheme in the various activities sections will be dependent on a good planning and management of reuse processes founded on an actual water request and good institutional, and organizational status.

It is necessary to evaluate if the usage of reclaimed effluent is economical and financially feasible. Technical side require also more studies, besides applying researches for every particular implementation. Education, data, and training of farmworkers and related services also show a significant part in encourage these practices aiming to attain more agricultural production without bad side impacts on the ecosystem.

The shortage of dependable datum on present situation of effluent qualities and quantities and the lack of clearly known reuse plan, which depends on economic and health foundation, make the reuse of reclaimed effluent realistic in Gaza Strip. Alongside the treatment needs and the wastewater quality for various reuse targets, other aspects should be taken in consideration, social and economic sides and regulations and standards in the region.

2.10 Case Studies

There is a growing all over the world of using of RO based technology in wastewater reclamation especially in the last decade. The experiences obtained over the years of operating of present reclamation plants has been a fundamental side to expansion and growth of this technology. There are numerous RO plants in the world in operation which can be classified as mega-sized plant as shown in (figure 2.1). These plants have the ability to produce enormous amount of effluent with quality compared to potable water quality. These have all become an essential facility to support the water-scarce regions.

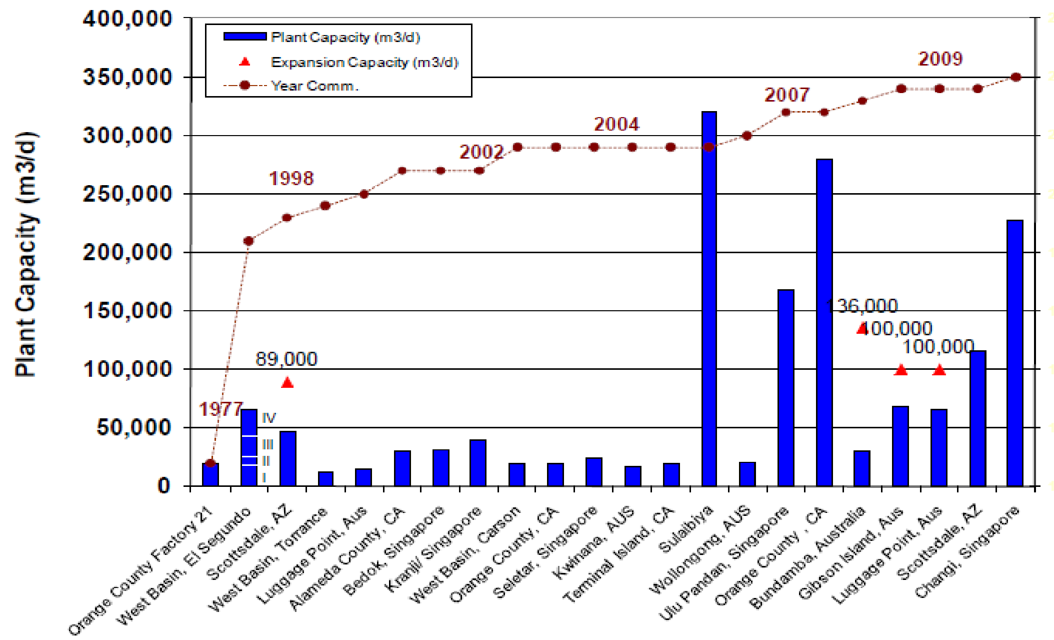

Figure (2.1): Wastewater reclamation plants

2.10.1 Sulaibiya Wastewater Reclamation Plant in Kuwait

Sulaibiya Effluent Reclamation Plant, located in Kuwait, was commissioned in 2004 after two years and half of construction with total cost of ($422M), the Sulaibiya effluent reclamation plant won global water awards as The Wastewater Project of the Year in 2005 after short time of initiation. The plant is at the present time by far the biggest treatment plant of its type in the globe to use membrane-based water treatment technologies such as reverse osmosis (RO) and ultrafiltration (UF). Currently, the capacity is to 375,000 m^3/day and to reach the capacity of 600,000 m^3/day.

The Sulaibiya plant consists of three processes; biological treatment, dual membranes filtration (RO / UF) and sludge processing. Sulaibiya purify wastewater to potable water quality for non-potable utilization such as agricultural, industrial and aquifer recharging purposes. At full operation, the plant is anticipated to cover 26% of Kuwait's gross water needs, which reduce the yearly demand from non-potable sources from 140 MCM to 25 MCM (water technology, 2018).

2.10.2 Groundwater replenishment scheme in Orange County, USA

Orange Country Advanced Water Treatment, located in California USA, was opened in 2004 and its effluent offers supplement sources of effluent to Orange County, California for seawater intrusion barrier and for groundwater recharge. The facility treats 320,000 m^3/day of treated effluent to be expanded to reach capacity of 590,000 m^3/day of product.

The treatment plant consists of three main treatment process; MF, RO and advanced oxidation process (AOP) with UV light with hydrogen peroxide. The influent, which is partially treated wastewater, is treated firstly using microfiltration unit. Microfiltration processes remove tiny suspended components from the wastewater. The wastewater is then purified through RO, which eliminate most of residual solids and pollutants by penetrating the pumped water across membranes pores. Water quality effluent after this process is almost distilled. Then the water is processed with UV rays and hydrogen peroxide as a preventive measure. Merging UV rays and hydrogen peroxide produces advanced oxidation reaction and reject any residual of organic matters.

This multi-stage processes produces water with quality better than other conventional water sources available to the Orange County area. The full-scale treatment plant insure that removal of all contaminants can be possible to reach the drinking water standard using an advanced treatment process consists of MF, RO, and AOP treatment. After RO treatment, the product water is so low in salt & mineral content. (Water technology, 2018).

2.10.3 Changi Water Reclamation Plant, Singapore

Changi Water Reclamation Plant (CWRP), located in Singapore, considered one of the largest and most advanced wastewater treatment plant in the globe. It was opened in June 2009 with a capacity to treat 800 m^3/day of wastewater. The plant will be extended to reach a capacity of 2400 m^3/day. Effluent at the CWRP is purified by rejection the solids and pollutants presented in the wastewater. Then the effluent water is disposed to the ecosystem or conveyed to NEWater treatment plant for advance treatment.

NEWater is the backbone of Singapore water sustainability plan and currently covers one third of the total water country demand. At NEWater facilities, the treated wastewater is treated using advanced dual membrane and ultraviolet to reach potable water quality. The NEWater production operations use advanced dual membrane and ultraviolet techniques as a post treatment for effluents from CWRP. Currently, there are four NEWater facilities in Singapore. The latest and the largest one, Sembcorp NEWater plant, was commissioned in May 2010 with a capacity of 50 MGD. (Water technology, 2018).

2.10.4 Bundamba Advanced Water Treatment Plant

Bundamba Advanced Wastewater Treatment Plant (AWTP), located in Ipswich, Australia, was built in two stages with total cost of $380m, construction of the plant has started in September 2006 with capacity to treat 66,000 m^3/day of treated water. The plant became fully operational in June 2008.

Lamella pre-treatment clarifiers in Bundamba plant, with the area of 5,000m^2, have a capacity to treat up to 100,000 m^3/day of wastewater, consist of microfiltration and reverse osmosis building, which have three core treatment processes, which is microfiltration, reverse osmosis (RO), and advanced oxidation processes.

The microfiltration process involves passing the wastewater through a fiber membrane with 0.014 microns wide pores diameter. Then the effluent passes with high pressure throw 65 RO membrane with 18 in diameter. This removes all particulate matter, and other pollutants from the wastewater. Advanced oxidation uses ultraviolet (UV) irradiation and hydrogen peroxide to eliminate the residual organics in the water. Lime and carbon dioxide are added to purified water to harden water and to increase its alkalinity. The effluents from the plant have high quality and can be safely used or sent to reservoirs or power stations (Water technology, 2018).

Chapter 3:
Study Area

Chapter (3):
Study Area

3.1 Introduction

Gaza governorates are situating in the southeastern coastline of Palestine. The Gaza governorates are a narrow strip of land on the Mediterranean coast. In 1948, the Gaza governorates had a population of less than 100,000 people. By now, the number of the population in Gaza governorates is over than 1.899 million people distributed across five Governorates (figure3.1) (PCBS, 2017). Thus, Gaza holds the highest population density in the world over than 5000 persons per square km.

Gaza Strip has a semi-arid climate and is located in a transitive area between a moderate Mediterranean climate to the north and west, and the barren Negev and Sinai deserts to the south and east. Gaza Strip has a temperate winters and arid hot summers. Rainfall in Gaza strip is unequally distributed over governorates it varies by a notably large amount by from the North to the South with annual average rainfall of 372 mm (PWA, 2012a).

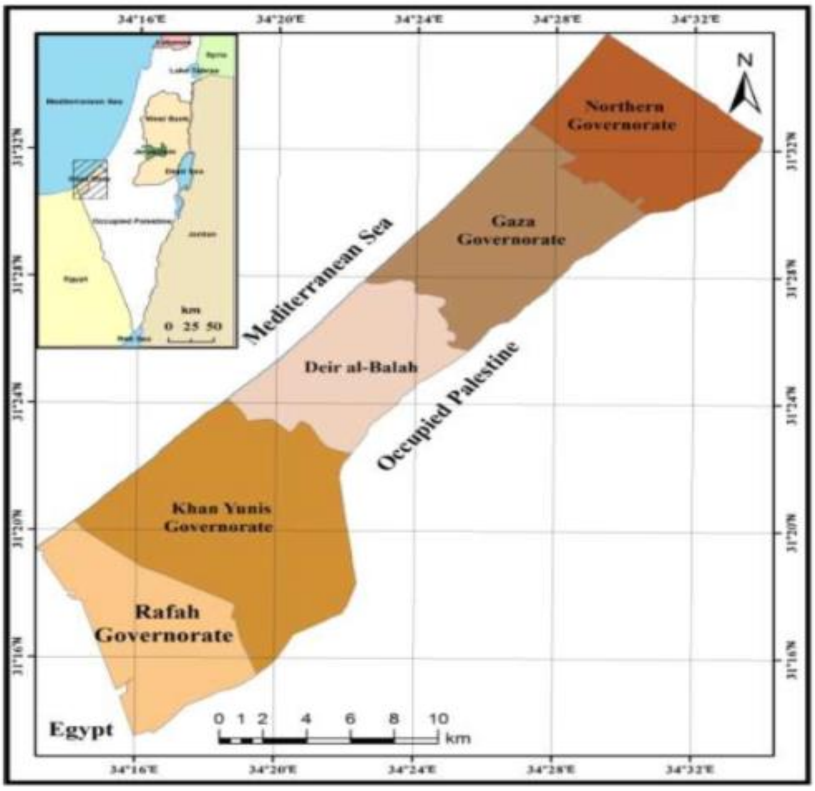

Figure (3.1): Gaza Strip Governorates

3.2 Water Resources in Gaza Strip

3.2.1 Groundwater

Groundwater is the master source of water in Gaza Strip where the coastal aquifer is the only source for water, with the depth of the water containing layer diverges from some meters in the eastern and southeastern zones to less than meter and half in the western zones and align the coastline. The aquifer composed mostly of sand, gravel and granular sand (Korkar) mixed with silt and clay. A rigid layer of clay with low permeability has a depth of less than one meter located under the aquifer. The annual recharge amounts for the aquifer is approximately 60 MCM. The total abstracted volume is about 180 MCM, this shows that the whole recharge is only one-third of overall extraction. These unsustainably high rates of abstraction have led to decrease the groundwater levels, consequently gradually intrusion of seawater and upwelling of saline groundwater occurred (PWA, 2012b).

The Water quality in Gaza Strip is very poor where the major problem is the high concentrations of salts. The water quality didn't meet the accepted international guidelines for potable water usage, only about 5% of water pumped through the network meets drinking water standards (World Bank, 2009). At the present time, more than a few of agricultural wells are also viewing high saline levels. The chloride concentration of the abstracted water is varied from 100-1000 mg/l, while the nitrate is varying from 50-300 mg/l. (PWA,2013)

3.2.2 Non-conventional water resources

According to (PWA, 2013), Gaza cannot supply itself but must find new alternative sources of water as:

I-Purchased water (Mekorot)

Gaza presently buys amounts of its water from the Israeli water utility (Mekorot): Israel is under a commitment to supply 10 MCM and there is an addition 5 MCM is under the interim agreement and negotiations through the implementation of those pledges with an initial price agreed (PWA, 2013).

II- Desalination plants

Purification of brackish water to obtain adequate levels of potable water quality is an significant choice which were performed at minor scale. About 3 MCM per year is supplied from about one hundred private water suppliers (brackish water desalination) besides to single public seawater desalination plant and about six pubic brackish groundwater desalination plants managed by municipal departments and CMWU.

The PWA newly finished a research of water supply choices for the short-term, medium-term and long-term. At the short-term, low-volume (STLV) seawater desalination plant to be built with an overall capacity of 13 MCM per year. In the long terms central seawater desalination plant will be built with a capacity of 50 MCM per year by the year 2017-2022 to be extended to 129 MCM/y in the future (PWA,2012b).

III- Treated wastewater reuse

Wastewater reclamation and reuse appear to be encouraging in the Gaza Strip near future. The predicted quantity of effluent to be used for agriculture will gradually increase on the coming two decades saving more than 50%of groundwater that required for agriculture (Tubail et. al., 2003).

There are several of latest researches, which have indicated that the farmworkers in Gaza Strip are willing to use reclaimed effluent for irrigating agriculture, if amounts of it was accessible. The reuse of reclaimed effluent is highly significant because around 50% of the current potable water use in Gaza Strip is allocated to the agricultural strip. The reuse can't be offered at any considerable scale if there is a lack of high quality effluent treatment (PWA, 2011).

3.3 Wastewater in Gaza Strip

3.3.1 Present situation of wastewater in Gaza Strip

The environmentally right management of waste demand appropriate collection, treatment and reuse of reclaimed wastewater. In Gaza Strip wastewater, some areas linked to sewage facility and served by well-functioning system while some areas not linked at all to the sewage system and depends on cesspits as wastewater disposal method. On average, it is estimated that about 70 % of the areas in Gaza Strip are linked to a sewerage network. (PWA,2013).

There are five treatment plants in Gaza Strip; North Gaza, Gaza Central, Wadi Gaza, Khan Younis and Rafah, neither one of them is functioning effectively may be except the new one in north Gaza. Around 75-80 % of the municipal effluent generated in Gaza is disposed into the ecosystem without enough proper treatment or without any treatment at all in overload treatment plant cases or leakage after collection in cesspits.

Based on the per capita effluent produced, the total amount of effluent produces for the year 2015 was generated in the Gaza Strip is 50 MCM, of which 36 MCM passes into sewerage networks and the remaining collecting in cesspits. (ARIJ,2015c).

Table (3.1): Estimated amounts of wastewater produced in Palestine in 2015

Governorate	Amount in MCM
North Gaza	10
Gaza	19
Dier Al-Balah	7.5
Khan Yunis	8.5
Rafah	6

The major goal of the treatment plants is to produce effluent with quality suitable for non-potable use such as irrigation or even discharging into groundwater. Although, as a outcome of the poor quality of the reclaimed effluent, which is away below WHO guidelines and Palestinian standards for use in irrigation or discharging, also the plans for delivering treated wastewater to agricultural areas were never completed

3.3.2 Wastewater Composition in Gaza Strip

Total wastewater for the Gaza strip is estimated at 50 MCM (ARIJ, 2015c; PCBS, 2013c, 2015c).

It has noticed that there in high organic matters and high salinity in the row sewage because there is a low water consumption per capita. The biochemical oxygen demand (BOD5) level of sewage in Gaza averages is 686 mg per liter. This is far above than the average BOD5 levels in many developed countries which ranges from 200-300 mg per liter (Polprasert, 1996).

Table (3.2): Anticipated amount of effluent generated in Gaza Strip in 2015

Parameter	Wastewater Characteristics		
	North Area	Gaza	Rafah
BOD5(mg/L)	728	667	777
COD(mg/L)	1385	1306	1399
SS(mg/L)	663	617	540
SS/BOD	0.9	0.95	0.69
BOD/COD	0.526	0.51	0.56

3.3.3 Wastewater treatments in Gaza Strip

Sanitation services in Gaza Strip are in crisis, the existing wastewater treatment plants function intermittently, so some wastewater is being treated and the large amount is returned row and pumped to sea (World bank, 2009).

Based on the (CMWU, 2012). the amount of effluent has based on the composed samples gathered from the WWTPs. BOD, COD and TSS parameters were monitored at a monthly basis during three last years. The result of parameters to all treatment plant can be shown in Table 3.3. Gaza WWTP has better quality effluent for irrigation than that for Beit Lahia, Rafah, and or Kan - yonis WWTP.

Table (3.3): Efficiency of existing effluent treatment plants (Gaza Strip)

WWTP	BOD			COD			TSS		
	Inf. mg/l	Eff. mg/l	Removal %	Inf. mg/l	Eff. mg/l	Removal %	Inf. mg/l	Eff. mg/l	Removal %
Gaza	500	105	79	1020	220	78	550	110	80
Rafah	560	120	81	1160	255	78	550	122	79
KhanYunis	520	155	70	1090	322	70	580	141	76
Beit Lahia	440	133	70	980	250	74	480	222	71

I. Existing wastewater treatment plants:

There are five effluent reclamation plants operating in Gaza Strip: North Gaza wastewater treatment plant (NGWWTP) in the north, Gaza wastewater treatment plant (GWWTP) in the Gaza city, Wadi Gaza wastewater treatment plant (WGWWTP) in the middle, Khan Younis and Rafah wastewater treatment plant (KY, R WWTP) in the south.

The present effient treatment plants in Gaza are over-loaded and are extremely ineffective and barely functioning. The treatment ineffective had been ascribed to shortage of suitable operation and maintenance; undependable of power supply, and there is a difficulty of supplying spare parts due to Israel blockade. The Mediterranean Sea acts as the final destination for disposal of high treated, partially treated or even raw effluent in Gaza Strip (CMWU, 2012).

Moreover, the general characterization of municipal wastewater are shown in (Table 1.3). It is obvious that variety of treatments are available in all areas.

Table (3.4): General characteristics of effluent treatment plants (ARIJ, 2015c)

Municipalities WWTP	Types of treatment	Construction date	Effluent quantity m3/d	Effluent disposal destination
North Gaza (New)	Aerated ponds, bio-towers	2018	35000	Infiltration basin
Gaza	Anaerobic ponds followed with bio-towers	1979	65000	Seawater
Wadi Gaza	Anaerobic ponds followed with bio-towers	2014	12000	Seawater
Khan Yunis	Anaerobic ponds followed with bio-towers	2007	13500	Seawater
Rafah	Anaerobic ponds followed with bio-towers	1987	13000	Seawater

II. Future Wastewater Treatment Plants:

It is planned that these five current WWTPs will be replaced by three new WWTPs: North, Central and South. The North Gaza wastewater treatment plant (NGWWTP) recently entered the service and this WWTP replaced the old plant at Beit Lahia also Gaza and south WWTPs is under construction and it will be ready by 2022. The planned upgrade will replace the current over-loaded facilities with higher capacity facilities in order to enhance treatment plants efficiency and improve the quality of effluent being disposed into the ecosystem

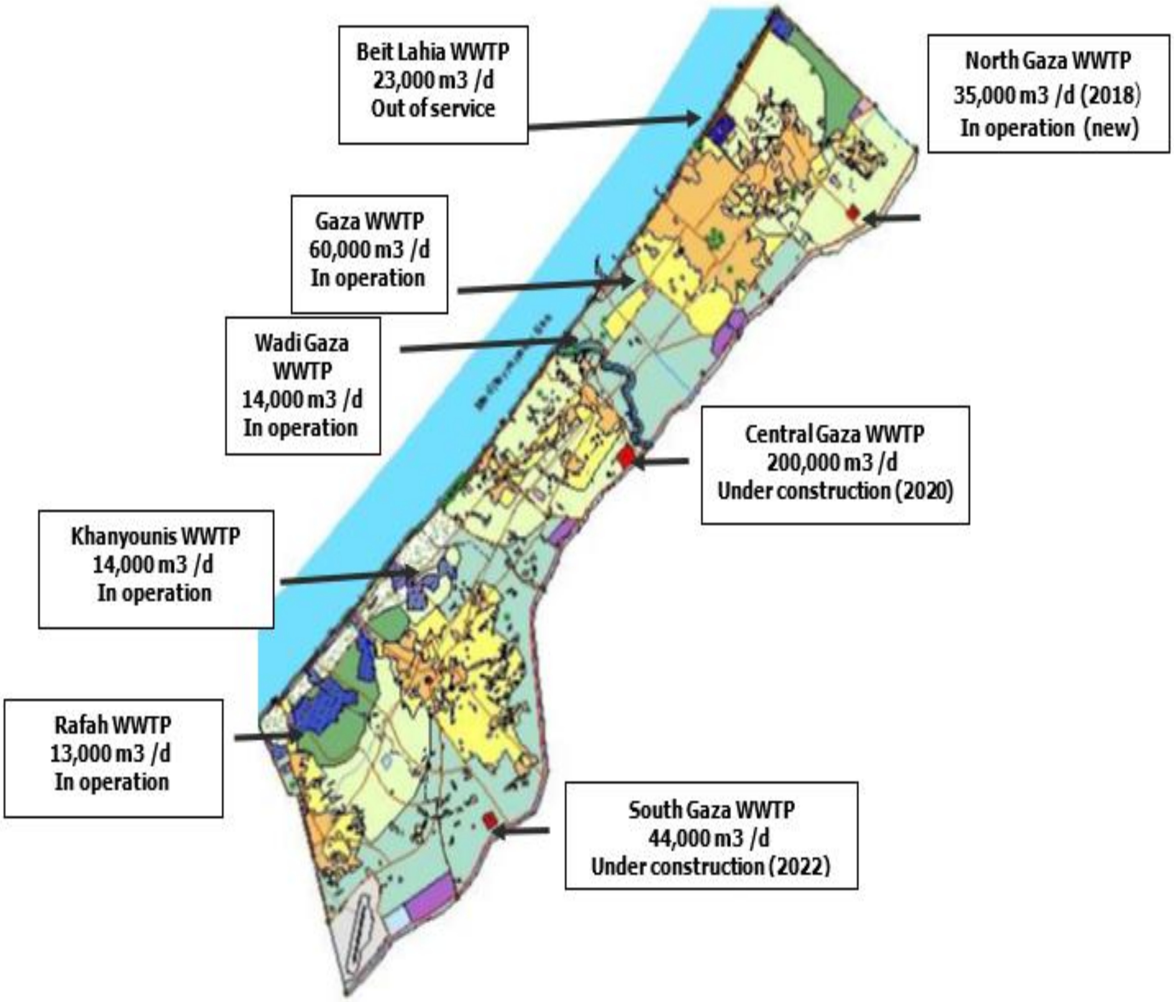

Figure (3.2): Current & future WWTP

Table (3.5): Current and Future WWTPs

Name of Wastewater Treatment plant	Actual Flow	Status of Current WWTP	Future of WWTP	Final Destination
North Gaza (NGEST)	35,000	North Gaza WWTP opened in 2018 to replace Bait Lahia WWTP which is now out of service	NGEST will upgrade to reach capacity of 70,000 m3/d	Infiltration Basin
Gaza Central	65,000	Commissioned in 1979 and then upgraded and expanded over the years, now the plant is overloaded with capacity of 50,000 m3/d	Central WWTPs will replace the current plant with capacity of 200,000 m3/d it will be operated in 2020	Sea water
Middle	14,000	Established in 2014, started with capacity of 12000m3/d		
Khanyounis	10,000	Three lagoons were built in Almawasi and Alamal area to collect and partially treat wastewater during period from 2003 to 2009 then dispose the effluent into see	South Khanyounis WWTP will replace current plants with capacity of 26,000m3/d as phase I will be operated in 2019 and 44,000 m3/d it will be operated in 2025	Infiltration basin
Rafah	13,000	Commissioned in 1989, with treatment capacity up to 4,000 m3/d. then upgrade to reach 20,000m3/d capacity		

3.4 Strategy for the development of reclaimed effluent reuse in agriculture

Over the last ten years, some small scale pilot projects have been started in Gaza Strip for experiment, testing and substantiation purposes, the results of these trials (with an additional of regional experience) have been enough to assist and encourage immediate development to the next level which medium sized reuse schemes, expanding over a few thousand dunum.

The short-term plan aims to perform such programs from WWTPs effluent. These pilot projects will not wait until a new institutional framework or new agencies to be created and then make arrangement for these projects and make it formal. Actually, these can be performed now throw the present agencies: PWA, MoA, water utilities and farmworker's associations. In order to gather and motivate the farmworkers quickly, awareness raising campaigns will be done to notify possible users of the advantage and safety of treated wastewater reuse. The use of social media will be considered as a significant means of encourage reuse and its connected advantages.

Opportunities for the future development of reclaimed effluent reuse will be examined, also taking into consideration the environmental and health concerns.

As listed in Table 3.4, volume of treated wastewater that has been used in 2012 is 1 MCM which is only 3% of the available partially treated wastewater. In the short strategy it is expected that percent will reach 25% (15MCM/year by 2022) and in the long strategy it will reach (25MCM/year by 2032) for agriculture and (75MCM/year 2032) for aquifer recharging.

Table (3.6): Potential reuse of treated wastewater (PWA, 2013)

		Long term strategy		
Situation (years)	**2012**	**2022**	**2027**	**2032**
Reclaimed Wastewater suitable for irrigation or groundwater infiltration (MCM/year)	33.2	59.3	75.8	99.9
Irrigation portion	3%	25%	25%	25%
Resource for reuse in irrigation (MCM/year)	1	14.8	19	25
Residual resource for infiltration (aquifer Recharge) (MCM/year)	32.2	44.5	56.9	75

		Long term strategy		
Ground Water resource in Irrigation (MCM//year)	86	59	45.5	32
Dams for Irrigation (MCM/year)	0	5	7.5	10
Total Available quantity for Irrigation (MCM/year)	87	78.8	72	67
Irrigable land (dunum)	133000	123000	118000	113000
Irrigation needs	741	741	741	741
Potential irrigated land (in dunum)	117403	106383	97112	90401
% of irrigable land	88.3%	86.5%	82.3%	80%

The coastal aquifer has been over-used in last decade. the long-term plan aims to decrease overall groundwater abstraction in the Gaza Strip from the present rate of 180 Mm3/year to 70 Mm3/year in 2032. As shown in table 3.5 the long strategy aims to reduce the dependability of coastal aquifer and to increase the amount of wastewater reuse specially for agriculture, also it has noticed that the total anticipated demands of water for agriculture will be reduced because some areas will become residential due to the increase of population it's anticipate that the 11600 donum in 2012 that used in agriculture will be 90000 by 2032.

Table (3.7): Anticipated wastewater reuse for agriculture (PWA, 2013)

Sources/years	2012	Long term strategy
Coastal aquifer (MCM/year)	86	32
Wastewater reuse (MCM/year)	1	25
Damns (MCM/year)	0	10
Total (MCM/year)	87	67

Chapter 4:
Methodology

Chapter (4)

Methodology

The purpose of this study is to assess the performance of Reverse Osmosis in improving the quality of effluent from Gaza wastewater treatment plants through a field experiment set up, laboratory tests for treated samples and analysis the results. This chapter consisted of experiment layout, sand filter design, filters specification, sample collection and analytical work.

4.1 Data collection

Various data and information related to using of RO membranes as wastewater post treatment for non-potable uses were gathered including previous reports, researches, articles, journals and similar international projects.

4.2 Field Experiment

4.2.1 Experimental set up and procedure

- **Site**

  The field experiment was conducted in Islamic University laboratory in two trials, first trial was on 20/02/2017 and after some enhancement to the set especially for the pretreatment (sand filter), the experiment was held again on 02/04/2017.

- **Wastewater source**

  The wastewater was collected from effluent of Gaza WWTP and translocated to experimental site by using barrels approximately 500 liters of wastewater was used in each experiment trial of experiment.

- **Experiment layout**

  The layout of the experiment is presented in Figure 4.1. It consists of feeder tank, sand filter as pre-treatment unit, microfiltration unit, Reverse osmosis unit and the both of permeate and concentrate tanks.

  First, samples from WWTP was put into feeder tank, passes throw sand filter, which is composed of multi-size gravel to operate more efficiently, then entered into the three stages of sediment prefilter which is MF/UF membrane unit with 5 and 1 micron pores diameter, then pumped throw RO membrane unit then the treated water go to (tank3) for water permeate, which is our product to be tested in lab later and (tank4) is for Concentrated water, which will be returned to (tank 2) to pass throw the MF & RO membrane again.

Figure (4.1): Layout of experiment

4.2.2 Sand filter design

In the first experiment trial, the sand filter consists of 10 cm sand stone, 15 cm shells, geotextile infiltration sheet and 20 cm sand but in the second experiment it has modified to set of three layers of gravel differs in size, the largest is 9.5 mm, the medium is 4.75 mm, the smallest is 2.37 mm and sand layer, the depth of each layer 10 cm, geotextile infiltration sheet was put between layers as shown in Figures 4.3 ,4.2

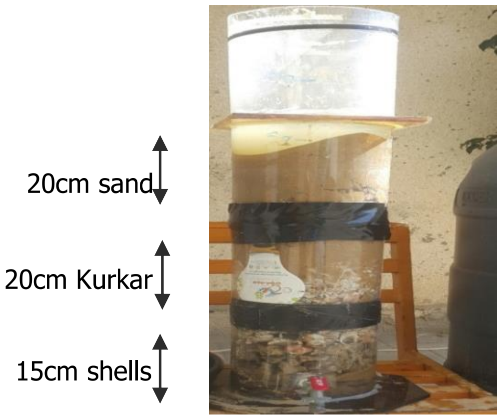

Figure (4.2): sand filter configuration 'trial1'

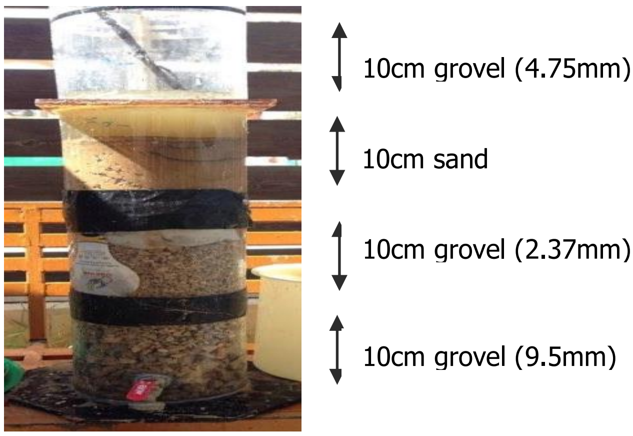

Figure (4.3): Sand filter configuration 'trial2'

4.2.3 Microfiltration/Ultrafiltration Unit

Three stages of prefilter sediment cartridge with 1 & 5-micron pores diameter was selected to be a second pretreatment unit after sand filter to protect the RO device from fouling and to reduce suspended solids. The three stages shown in figure 4.6

4.2.4 Reverse Osmosis Unit

Housing RO unit has chosen, the flow of the filter was 1.8 L / minute, the pressure was 130 psi which equal 8.844 bar, the recovery rate was 20 % from the fed water. The filter device is shown in figure 4.4

Figure (4.4): Reverse osmosis filter unit

4.3 Sample Collection

Four samples were taken in every stage of filtration in each of two trials experiment. The samples were put in polythene bottles that were pre-washed with acid and distilled water and then were dried. First sample was taken from the feeder tank and before sand filter, the second was taken after sand filter, and finally two samples were taken from RO concentrate and permeate tanks. Then the samples were preserved at 4°C in an ice box and brought to the laboratory at Islamic University of Gaza Testing Laboratories

Figure (4.5): Sample collection after RO

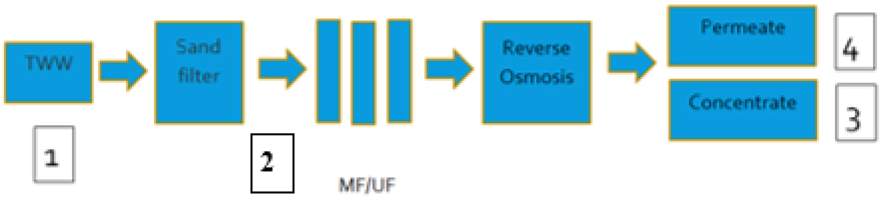

Figure (4.6): Experiment Layout and samples location

4.4 Analytical Work

Quality of the treated wastewater in every phase of the experiment was tested in order to examine the parameters such as: Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Hydrogen Ion Concentration (pH), Temperature (T), Electrical Conductivity (EC), Fecal Coliform (FC), and Nitrate (NO3-N). Tests were performed at Islamic University of Gaza laboratory.

4.4.1 Biochemical Oxygen Demand (BOD5)

BOD was measured using OxiTop measuring system according; the quantity of samples was taken after well mixing according to corresponding measuring range recommended in the manufacturer manual. The samples discharged into OxiTop bottles followed by placing a magnetic stirring rod. Rubber quiver integrated in the neck of the bottle then three tablets of sodium hydroxide were put into the rubber quiver with a tweezers. OxiTop bottle was directly tightly closed and pressed on S and M buttons simultaneously for two second until the display shows 00. The bottles were placed in the stirring tray and incubated for 5 days at 20 ºC. Readings of stored values was registered after 5 days by pressing on m until values displayed for 1 second (modified from OxiTop Manual).

4.4.2 Fecal Coliforms (FC)

The concentration of fecal coliforms organisms in water is measured to determine the probability of pollution by micro-biological bacteria. The membrane filter method is a standard method for the testing of Water and Wastewater, gives direct counts of the fecal coliform collection without enrichment or following tests. The results of the membrane filter test take less than 1day. An adequate amount of water sample is pushed through a membrane filter that retains the microorganisms that existing in the sample. The filter comprising the bacteria is put on MFC agar in a petri dish. The dish is incubated at temperature of 44.5 ± 0.2°C for 24 ± 2 hours .

After incubation, the representative colonies of bacteria are calculated under low magnification and the number of fecal coliforms is reported as colony forming units per 100 ml (CFU/100 mL) of water sample.

4.4.3 Suspended Solid (TSS)

To examine the total suspended particles in water and wastewater, an appropriate volume of water sample is pushed through a weighed standard glass-fiber filter and the remains kept on the filter is dried with temperature of 103°C to 105°C to reach fixed weight. The increase in weight of the filter is the weight of the total suspended particles. If the suspended solids block the filter voids and extend the time of filtration, increasing the diameter of the filter opening or decrease the sample volume may be necessary. To get an estimate of total suspended solids, subtract total dissolved solids from total solids.

4.4.4 Nitrate (NO3-N)

As mentioned in (El –Nahhal, 2014). NO3 concentration in wastewater is determined according to salicylic acid method. In this method 5 g salicylic acid dissolved in

100ml H_2SO_4. Then 2ml of the solution was transform to test tubes contained the 1ml of standard solution concentration.

The system is left for 20 min. to allow the reaction. The 18 ml of NaOH 6N is added to the tubes. A yellow color of salicylic acid is developed. The color in the standard solutions and known samples were measured at 420 nm. The liner relationship between the optical description and concentration was used to determine the NO_3 concentration in the others samples.

4.4.5 pH

PH is a measure of the hydrogen ion concentration in water. PH measured using a pH meter, firstly the device has to be calibrated by measuring pH for a matter with a known pH number, them meter has to be adjusted to match the sample temperature.

4.4.6 Electrical Conductivity (EC)

EC is considered as a big indicator of water salinity. The more solids content or total dissolved solid (TDS) in water the more of EC value number. EC can measure by EC meter. First Calibrate the EC meter and then Measure conductance of samples then we report the reading. EC is measured in dS/m. TDS value can be estimated by equation TDS (ppm) = 640*EC (dS/m)

4.4.7 Total Dissolved Solid (TDS)

TDS refers to total dissolved solids particles contained in water the solids. TDS can be measured by evaporating the water passed from TSS test at 180°C for one hour, TDS can also be estimated by measuring EC and using the previous mentioned equation or simply TDS can measure by TDS meter. TDS is measure in ppm or mg/l

Chapter 5:
Results and Discussion

Chapter 5:
Results and Discussion

This chapter explains the results of experiments and shows the performance of the used system (as a total), the efficiency of each component and the behavior of RO membranes in treating wastewater. The results were compared with similar international and Palestinian standards for non-potable uses especially in agriculture uses.

5.1 Efficiency for using RO to treated wastewater

5.1.1 Removal efficiency of total suspended solid (TSS)

First trial: (20/02/2017)

The sand filter was able to reduce 20% of TSS. Concentrate from round 1 was fed again to MF & RO unit. It's clear that the removal efficiency of TSS in the first round for membranes was 87% and for the whole set in the first round was 89.5%. For the second round the removal efficiency for membranes was 66.5% and the system removal efficiency was 96.5% as shown in table 5.1.

Table (5.1): the result of TSS for experiment trial 1

Component	TSS (mg/l)	Unit removal efficiency	System removal efficiency
Before sand filter	1900		
After sand filter	1533	19.3%	19.3%
Brine	2867		
Permeate round 1	200	87%	89.5%
Permeate round 2	67	66.5%	96.5%

Second trial: (02/04/2017)

The removal efficiency of TSS in the experiment second trial was 87.1% for membranes and 92.4% for the whole set as shown in table 5.2.

Table (5.2): the result of TSS for experiment trial 2

Component	TSS (mg/l)	Unit removal efficiency	System removal efficiency
Before sand filter	236		
After sand filter	140	40.7%	40.7%
Permeate	18	87.1%	92.4%

The percent removal of solids in infiltration system depends on a lot of factors such as particle size and voids opening among soil particles. Total suspended solids are particles in wastewater that can be blocked by a filter. Our results demonstrated that sand filter system was able to remove high fraction of TSS the removal efficiency ranged from 20-40%.

It was clear that the sand filter compositing of coarse aggregate and sand layers which was used in experiment trial 2 increases the efficiency up to 20% more of removal of TSS than in experiment trial 1 that have sand filter compositing of sandstone and shells. Following the structure of sand filter in experiment trial 2 ensures better removal and expanding the life of MF and RO membranes.

MF/UF & RO also have high efficiency to remove the TSS due to the small pores of its membranes. MF & RO removal efficiency for our experiment was ranged from 50-70% and increased up to 80% in the second round and that's agree with Sulaibiya facility, which is designed to produce an effluent product with content not to exceed than 20 mg/l of TSS.

However, the wastewater quality from the source (GWWTP) varies from (TSS=1900) in the experiment trial 1 which was abnormal and (TSS=236) in experiment trial 2. The quality of treated wastewater has significant impacts on the system.

5.1.2 BOD5 Mean Removal Efficiency

If there is enough amount of oxygen, the aerobic biological de-composition of an organic matter in wastewater will be continue till all of the organic contaminant is consumed, through three various activities. It's clear that the system was able to fully remove all BOD5 in the both trials.

First trial: (20/02/2017)

Table (5.3): the result of trial 1 experiment of BOD5

Component	BOD**5** (mg/l)	**Unit removal efficiency**	**System removal efficiency**
Before sand filter	250		
After sand filter	190	24%	24%
Concentrate	230		
Permeate round 1	0	100%	100%

Second trial: (02/04/2017)

Countless studies and experiments have been carried out the rejection of organics and organic contaminant by using RO membranes, and have specified several unique aspects connecting with organic elimination. It is clear that RO have high efficiency to remove BOD as shown in table 5.3 & 5.4. Our result agrees with Sulaibiya facility, which is designed to produce an effluent product with BOD not to exceed than 20 mg/l.

Table (5.4): the result of trial 2 experiment of BOD5

Component	BOD**5** (mg/l)	**Unit removal efficiency**	**System removal efficiency**
Before sand filter	250		
After sand filter	15	94%	94%

Permeate	0	100	100%

5.1.3 Fecal coliform (FC) Mean Removal Efficiency

Table (5.5): the result of trial 1 experiment of FC

Component	FC (cfu per 100 ml)	**Unit removal efficiency**	**System removal efficiency**
Before sand filter	500		
After sand filter	0	100%	100%
Concentrate	10		
Permeate	0	100%	100%

Second trial: (02/04/2017)

Table (5.6): the result of trial 2 experiment of FC

Component	**FC (cfu per 100 ml)**	**Unit removal efficiency**	**System removal efficiency**
Before sand filter	2000		
After sand filter	100	95%	95%
Permeate	Nill	100%	100%

It can be seen that sand filters, were able to remove nearly 100% of FC as shown in table5.5 & 5.6. These results comply with previous report Culp ET, al., (1978). More support to our results comes from (Langenbach,2009), (lee and Oki, 2013) and (Hajjaj, 2011), who demonstrated the efficiency of high sand filter (1.5 – 2 m height) to remove FC from TWW. Since mechanism of FC, removal is similar to that find in TSS in both systems. In addition, RO have high efficiency to remove FC according to (Inżynieria Ekologiczna, 2011).

5.1.4 Nitrate (NO3) Mean Removal Efficiency

Second trial: (02/04/2017)

Table5.7 explains the ability of sand filter to increase NO3 in effluent water from sands and this is due to conversion of NH4 to NO3 through sands filter (nitrification process) that plant absorb it easily which is considered as nutrients to plant growth. Since concentration of NO3 in inlet sand filter very low less than 1 mg/ l, due to partial conversion of NH4 toNO3 led to increase concentration to outlet sand. RO also has high ability to remove NO3. It's clear that the system was able to fully remove all NO3.

Table (5.7): the result of trial 2 experiment of NO3

Component	NO3 (mg/l)	Unit removal efficiency	System removal efficiency
Before filter	0.4		
After filter	15		
Permeate	0	100%	100%

5.1.5 Removing Efficiency of TDS

Second trial: (02/04/2017)

RO have high efficiency to remove TDS approach to 87.8 % as shown in table 5.8. Our result agrees with GWR facility in Orange County which produces 280,000 m3/d of treated wastewater that is used to increase the groundwater and replenish the aquifer in the region that supplies local municipalities with potable water and suffer from seawater intrusion, using the advanced treatment process RO based plant. With low pressure and high rejection ESPA2 membranes the plants are used to make RO permeate with less than 50 mg/l TDS. Another example is the Sulaibiya plant which treat the partially treated municipal wastewater with average monthly salinity value of 1,280 mg/l TDS, with a maximum value of 1,800 mg/l. RO is used to purify the water to less than 100 mg/l TDS, as well as provide a second barrier to bacteria, viruses and other pollutants (Franks, 2004)..

Table (5.8): the result of trial 1 experiment of TDS

Component	TDS (mg/l)	**Unit removal efficiency**	**System removal efficiency**
Before filter	3360		
After filter	3360	0%	0%
Permeate	410	87.8%	87.8%

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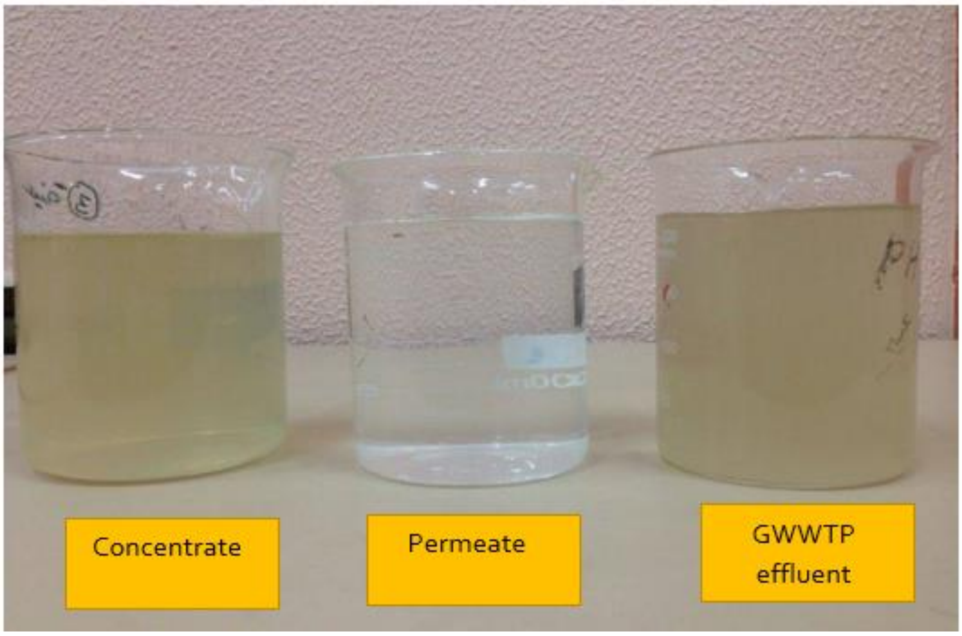


Figure (5.1): Samples before and after desalination operation

5.1.6 pH results

Second trial: (02/04/2017)

As seen in table 5.9, the pH of water rises from 7.7 to 8.7 after treatment which is alkaline. The normal pH range for irrigation water is from 6.5 to 8.4. So treated wastewater pH must be adjusted to use in agriculture irrigation.

Table (5.9): the result of trial 2 experiment of pH

Component	pH
Before filter	7.7
After filter	7.8
Permeate	8.7
Concentrate	7.8

Figure (5.2): MF/UF &RO unit

Figure (5.3): MF/UF cartridges after the experiment

5.2 Comparing the results with the Palestinian standards for non-potable usages

The table 5.10 and fig 5.4 shows comparison that pollutant values of the effluent treated wastewater achieves the Palestinian requirement for not-potable. The results show that the system is able to produce effluent with 236 mg/l of TSS which is below the required which is 40 mg/l of TSS. Also, the system able to fully elimination of BOD5, fecal coliform and NO3 which is better values that required from Palestinian standard. Also it has noticed that the TDS value is about 410 mg/l which is approximately half of the maximum required for Palestinian standard for agriculture. The system was able to produce quality compared to drinking water can be used easily and safety for non-potable uses as agriculture irrigation, ground water discharging or other purposes.

Table (5.10): Comparing the results with the Palestinian standard for reuse in agricultural purposes

parameters	Influent	Effluent	Palestinian standard for agriculture
TSS mg/l	236	18	40
BOD5 mg/l	250	0	45
FC colon/100ml	2000	Nill	1000
NO3- NO3 mg/l	0.4	0	50
TDS mg/l	3360	410	1000

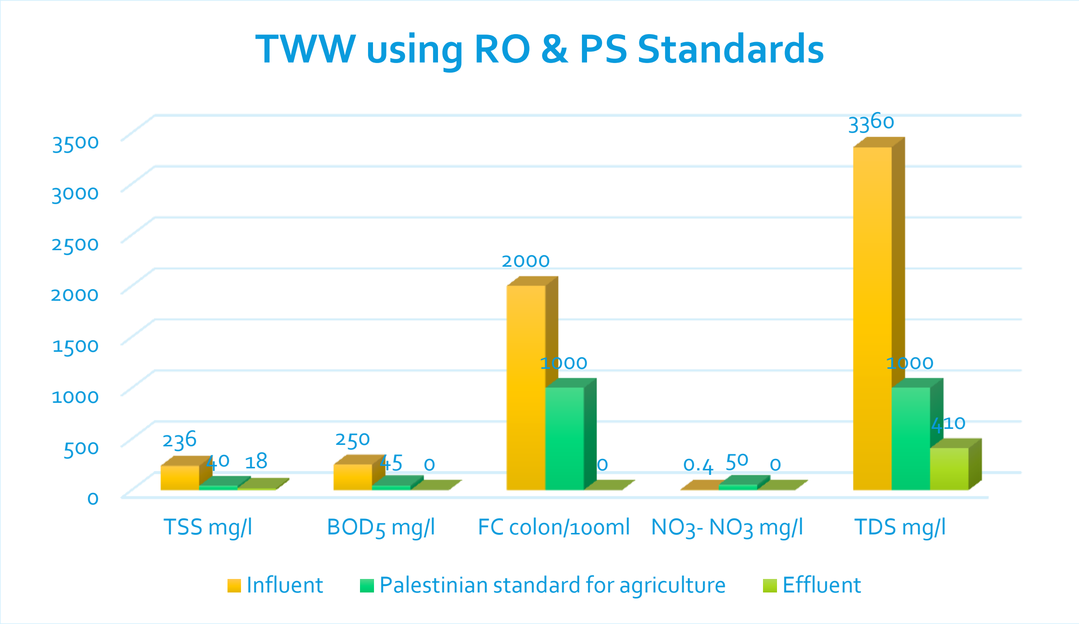


Figure (5.4): Comparing the results with the Palestinian standard for reuse in agricultural purposes

5.3 Energy Consumption

Specific energy consumption (SEC) for RO systems has commonly been calculated using over simple analyses that depends on average operation task for specific plant. A more sophisticated approach that consider many operational and water quality variables using statistical analysis. Variable parameters such as; flow rates, feed temperature and salinity degree, pressure applied, membrane fouling pressure losing, and system controls pressure losing as feed throttle valves.

Total desalination plant energy consumption can be measured by kWh per unit volume of effluent water. The energy consumption of our experiment was measured and it was 0.2 KW h /m3 whoever this number can't be representative number for all RO systems. As it was said, the energy consumption can be affected with various parameters and operation conditions. In the next chapter we will talk briefly about this point.

Chapter 6:
Cost Estimation

Chapter (6):
Cost Estimation

After the experiment part was performed and after the efficiency of membrane technology as a post treatment for Gaza wastewater plant was examined, estimation of the total cost and energy consumption has to be done to see if it is feasible to use this kind of treatment or not.

It was difficult to make estimation of the cost by experiments except to calculate the energy consumption roughly for this particular system, so in order to estimate accurately the total cost and the exact energy consumption, two methods were chosen. First method by make model simulate the experiment and see the output results. Second method by make comparison study with the two largest plants in the world Sulaibiya treatment plant in Kuwait and Orange country treatment plant in USA. Because both plants are working since while and produce hundreds of thousands cubic of reclaimed wastewater per day with stability and continuance, faced all challenges and constrains relating to using RO in reclamation wastewater as new technology.

6.1 Experiment Model

In order to make model simulate the experiment, Winflows program was chosen, which is one of the best programs for designing and simulation the operation of membrane systems. The program can simulate complex designs with a lot of scenarios. Pretreatment unit like cartridge filter can be added to the simulation to better represent the reality. Winflows also has some key new features that might not be found in similar software offered by other manufacturers including:

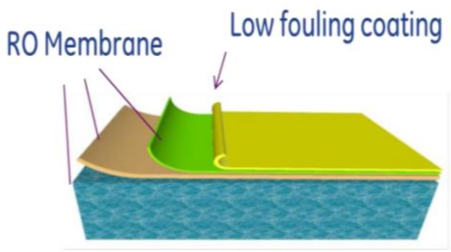
- 3 Pass systems
- Permeate Split and Recycle
- Antiscalant Dosing
- Energy Recovery Devices
- Ability to Combine stages

The model was designed to treat 1000 m^3/hour of tertiary treated wastewater with assumed TDS 3800 and pH 7.8 with temperature 16C.

Table (6.1): Feed information

Feed Information					
Temperature, C	**16**	**RO-1:**	**16**		
Feed pH :	**7.8**			**Silt Density Index :**	**5**
Feed Stream Composition(mg/l): Source - Tertiary Treated Wastewater (Conventional)					

After some trials and errors, the system designed was consisted of Cartridge filter as pretreatment and two stages of RO elements, the first one consists of 90 pressure vessels, the second one consists of 65 pressure vessels, every vessel in the two stages contains 7 elements of Duraslick anti-fouling membranes which is membrane is designed especially for wastewater and coated with special layer to protect biofouling and increase life of membranes. The selected membrane model was DSL RO8040. It has been assumed that the membrane age will be 4 years each and there is pressure exchanger to recover the pressure



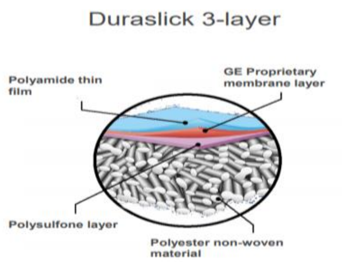


Table (6.2): Model design components

					Pre-stage Pressure Change, bar		**Permeate Pressure**	**Annual Change %**	
Stage	Housing	Elements	Element Type	Element Age (yr)	Boost	Drop	bar	A-Value	**B-Value**
1	90	7	DSL RO8040	4	0	0	0	15	**15**
2	65	7	DSL RO8040	4	0	0	0	15	**15**

As show in process date sheet from program, the model was able to reduce TDS to 300 ppm with recovery rate 50%, so the system will produce 500m^3/hour.

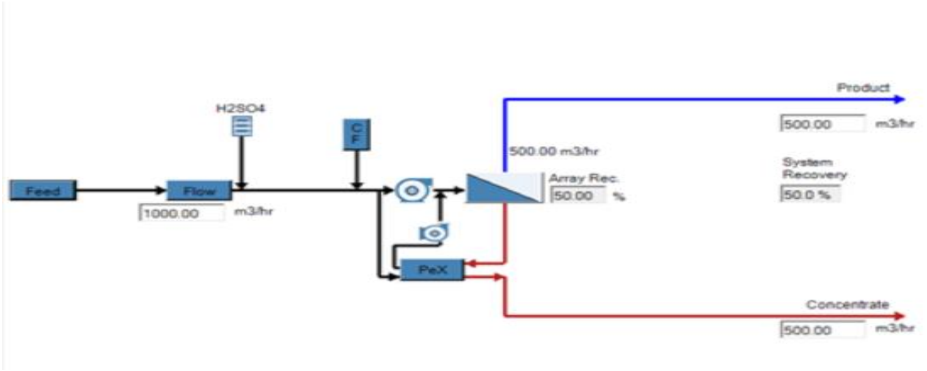


Figure (6.1): Model configuration

Table (6.3): Process data sheet

Process Data Sheet			
Flow Data	m3/hr	Analytical Data	mg/l
Raw Feed:	1000	Raw Feed TDS	3799
Product:	500.3	Product TDS	296.3
Concentrate:	499.7	Concentrate TDS	7307
System Data		Single Pass Design	
Temperature:	16		
Feed Flow to 1st Stage Housing	m3/hr	1000	
Feed Pressure	Bar	18.32	
Array Recovery	%	50	
Permeate Flow	m3/hr	500.28	
Split Permeate Flow	m3/hr	0	

6.1.1 Energy Cost

The pump data and energy recovery device were as shown in table, the main pump will consume 538.9 kW, however, EDR booster pump needed only 78.54 kW:

Table (6.4): Pumps data

Pump Summary		
Main Pump		
Feed Flow	m3/hr	505.1
Inlet Pressure	bar	2.78
Discharge Pressure	bar	18.32
Total Efficiency	%	80.1
Power	kW	538.9
ERD Booster Pump		
Feed Flow	m3/hr	495
Pressure Increase	bar	4.23
Efficiency	%	74.04
Power	kW	78.54
Total Power Consumption	kW	617.5

The specific energy consumption using ERD for whole system is 0.7kWh per 1m3 of permeate

Table (6.5): Power consumption for pumps

Calculated/Output Parameters		
Parameter		Value
Model		EX-140S
Number of Units	Number	21
Unit Flow	m3/hr	23.8
Lubrication Per Array	m3/hr	4.77
Lubrication Flow	%	0.96
Differential Pressure HP Side	bar	0.86
Differential Pressure LP Side	bar	0.75
Efficiency	%	90.31
Mixing at Membrane Feed	%	2.91
Power Savings	kW	188.2

Total Power Consumption	kW	350.7
Specific Power Consumption	kWh/m3	0.7
Specific Power Consumption	kWh/kgal	2.65
Power Cost Saved	$/year	2E+05

6.1.2 Estimated fixed cost

As listed in table below, estimation cost of applying the model as post treatment is about 6 Million USD and by assuming the age of membrane and vessels 5 years, the amount of water will be reclaimed is 15 MCM and therefore the cost of price is 0.4$ per one cubic meter of permeate.

Table (6.6): Estimated fixed cost for applying the model

Item	No	Unit Price	Total price
8" low fouling duaslick membrane	1085	1900	2061500
8" vessels (7 element per vessel)	155	4000	620000
Cartridge filter	8	3000	24000
Primary pump	10	5000	50000
High pressure pump	10	15000	150000
pressure exchange	2	50000	100000
dossing pump with tanks	2	10000	20000
pressure exchange	2	50000	100000
Dual media filters	4	7000	28000
Backwash pumps	4	3000	12000
flow meters	4	1000	4000
Skids	1	30000	30000
PLC	1	200000	200000
fittings and connections	1	100000	100000
h2SO4(kg)/6 years	45000	2	90000
Hanger and other plant structure	1	750000	750000
effluent and Permeate tanks 4000m3	2	800000	1600000
Total price			5939500
Amount of permeate per 5 years (m3)			15000000
Total cost per 1m3 permeate ($)			0.395966667

6.2 Comparison Study

6.2.1 Cost breakdown of RO treatment plant

The total cost is the cost being computed over the life cycle of a wastewater reclamation plant. This can be either built, operate, transfer (BOT) project contract period in Sulaibiya case it was 30 years of the mechanically and civil constructions technical life. This cost was compared to some of desalination plants in operation, under construction and being planned.

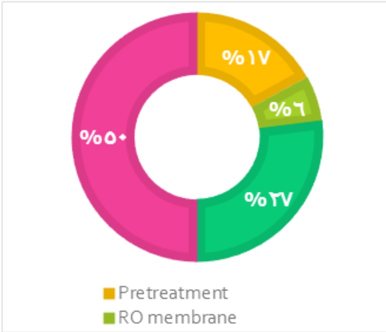
Generally, when conventional technology used as tertiary pre-treatment, the total cost of plant can be split as the following (Menge, 2001; Henthorne, 2005; Caneja,, 2005):

±17% Pretreatment

± 6% RO membrane cleaning and membrane replacement.

±27% Other fixed costs (amortization of facility equipment).

±50% Other variable costs (energy costs etc.)



When UF is chosen as pretreatment for RO as an alternative of the conventional technology, the total cost of plant spilt will be changed. All costs have been estimated below and the effects of using both of conventional and UF as pretreatment has been estimated for the individual costs.

6.2.2 Pretreatment cost

Several of different pre-treatment systems can be used as tertiary pretreatment to wastewater RO systems such as: flocculation, settling, disinfection, dissolved air flotation, sand filtration and membrane filtration.

With conventional technology as pretreatment, the pretreatment part of the total cost is about 17% of (85–90 cents/m3), equals (14–15 cents/m3). The pretreatment costs can be divided in amortization of investment and operating costs (coagulation and disinfection substances).

With UF technology, the total cost part will be reduced by 0–20%. The pretreatment part will be about (12–16 cents/m3). When UF is being chosen as pretreatment choice instead of conventional technology, the investment costs & fixed costs for the pretreatment will increase. The costs for coagulant chemicals will reduce, however a new cost appears which is the cost of UF membrane replacement. (Alhumoud,2010)

6.2.3 RO Membrane Replacement and Cleaning

With conventional technology as pretreatment, the RO replacement and RO cleaning part of the total cost is about 6% of (85–90 cents/m3), which equals about (5 US cents/m3).

With UF pretreatment, the total cost part of RO membrane replacement and RO membrane cleaning will be about (3–4 US cents/m3). The option over conventional technology, the RO cleaning usually will be considerably minimized. (from once every 2–3 months to once every 6–12 months). The RO membrane life time will be maximized because of the minimized RO fouling and the minimized chemical attack due to RO cleaning (Alhumoud,2010)

6.2.4 Other Fixed Costs

With conventional technology selected as pretreatment, the fixed costs part of the total cost is about 27% of (85–90 cents/m3) which equals (23–24 cents/m3).

The fixed costs are a function of the service time of the treatment plant; the shorter the service time, the more fixed costs will be. This is because the fixed costs are being calculated divided by the total net effluent production over the service life time. So, when the plant is not working, the net effluent production will be decreased and the fixed costs per m3 will increases.

With UF pretreatment, it is estimated that the overall reduction of cost will be about 4% in the other fixed costs. With UF technology, the total cost part of other fixed costs will be (22–23 cents/m3) (Alhumoud,2010)

Compared to conventional technology, UF will provide the following benefits:

- Shorter construction time, so the net effluent production will increase.
- RO plant will be operated more because the cleaning time is less frequency.
- Other fixed costs, such as land price.

6.2.5 Other Variable Costs

With conventional technology as pretreatment, the variable costs part of the total cost is about 50% of (85–90 cents/m3) which equals (42–45 cents/m3). With UF membrane technology the variable costs will also be (42–45 cents/m3). Although, less RO fouling will drive to a lower flux declination and consequently lower RO operating pressure. But, automation of UF is higher so the labor requirement costs will be smaller (Alhumoud,2010)

6.2.6 Total Cost of Ownership

With conventional pretreatment, the total cost of the wastewater RO plant is about (85–90 cents/m3).

With UF as pretreatment, the total cost of the dual membrane desalination plant will be (79–to 88 cents/m3). This offers a decrease in the total cost by 2–7% when compared to conventional pretreatment (Alhumoud,2010)

Besides, the UF pretreatment provides the following benefits:

- Extraordinarily smaller civil works and less construction risk.
- Small land prices with more freedom to construct.
- Water quality variations have almost no effect on RO performance.
-

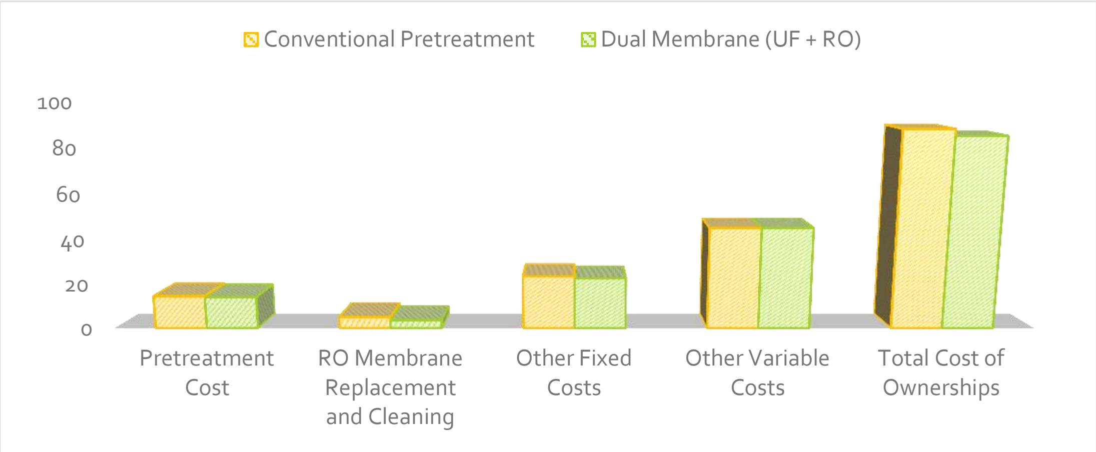


Figure (6.2): Comparison between total costs when using conventional or membrane pretreatment

6.3 Energy Cost

When taking about the implementation of RO based technology in purifying wastewater the main concern is the high energy cost which may reach up to half of the total cost as listed in the previous section. In this section we will review the energy cost for several water and wastewater resources and for different treatments methods.

6.3.1 Energy costs from conventional sources

The energy cost to produce potable water from natural sources as surface water and groundwater will different according the water quality and the treatment applied, the energy consumption for ground water treatment with additional membrane filtration as ultrafiltration or microfiltration is about 0.1 kWh/m^3, the energy consumption for surface water to be followed with conventional treatment then UF/MF membrane will be ranged from 0.25 to 0.35 kWh/m^3. In some regions like ours, because of seawater intrusion there is no fresh water resources they all became brackish especially the coastal aquifer so its need to have additional treatment and will consume more energy. Furthermore, the energy cost will be varied according to the brackish water salinity it will be ranged from 1 kWh/m^3 when the TDS under 3000 ppm and 1.7 kWh/m^3 for the TDS lying between 3000 and 11000 ppm which is may represent the majority of our country cases (Pearce, 2008)

6.3.2 Energy cost for wastewater reuse

The energy cost of wastewater reclamation will different according to the type of treatment applied and the effluent quality needed. Conventional activated sludge CAS (secondary treatment) then followed by dual membrane filtration mainly MF(UF) / RO consumption will be varied from 0.8 to 1.2 kWh/m3 which is almost similar to our experiment while membrane bioreactor MBR which didn't need any pretreatment followed by RO can consume energy between 1.2 and 1.5 kWh/m3 (Pearce, 2008)

6.3.3 Energy cost for seawater reuse

Seawater desalination energy consumption will be varied according to salinity of the water. For the Mediterranean Sea which have salinity about 38000 ppm which is moderate salinity among other ocean and seas. The energy consumption for pretreatment followed by RO desalination treatment will cost between 2.3 to 4 kWh/m3(Pearce, 2008)

6.3.4 Summary of energy costs from various sources

To sum up all the energy cost for different stages of treatment for water, wastewater and seawater, the energy consumption will be tabulated in table 6.7. As we seen the desalination of seawater is by far a greater consumer of energy, also it has been noticed that all types of wastewater treatment of consume less energy than brackish water as seen in figure 6.3.

Table (6.7): Energy usage for various water and wastewater

source	CAS (kWh/m3)	Pre-treatment (kWh/m3)	RO system (kWh/m3)	Total treatment (kWh/m3)
Groundwater + MF(UF)				0.1
Surface water + Conv. + MF(UF)				0.25-0.35
Brackish water (Up to 3000)		0.1	0.9	1
Brackish water (3000-11000)		0.3	1.4	1.7
Wastewater + CAS + Dual membrane	0.3-0.6	0.1-0.2	0.4-0.5	0.8-1.2
Wastewater+ MBR + RO		0.8-1	0.4-0.5	1.2-1.5
Mediterranean seawater		0.3-1	2-3	2.3-4

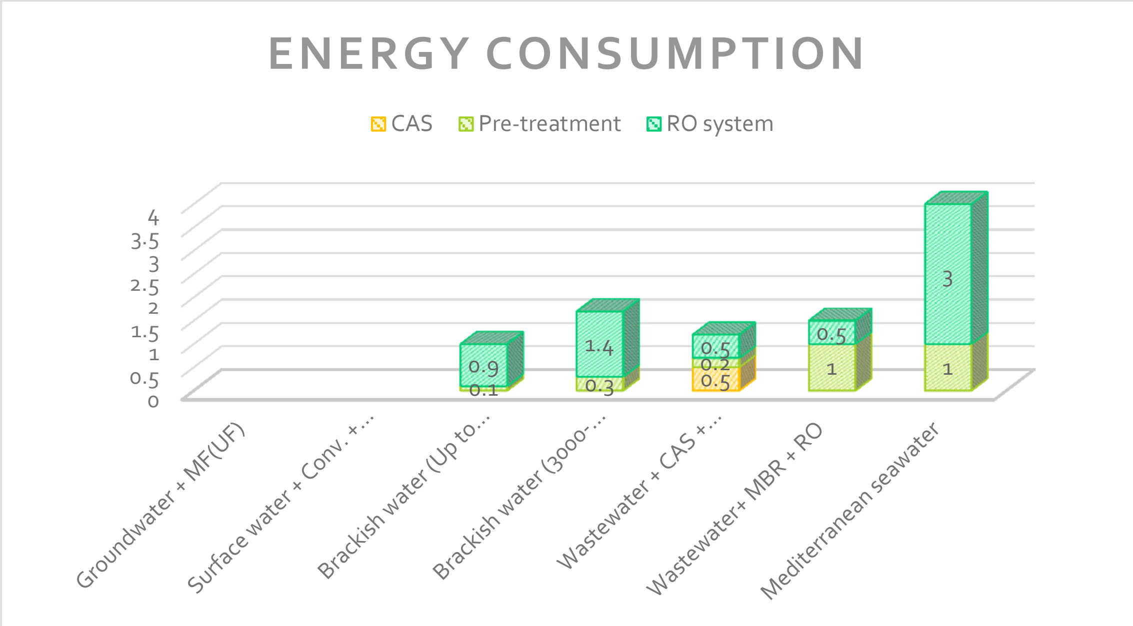


Figure (6.3): Energy consumption for different type of treatment

6.3 Conclusion

Post treatment for wastewater using RO technology became mature technology and its market has rapidly increased over the last fifty years and became more economically attractive and will be better through years.

It has been noticed that using membrane filtration like UF is better than conventional treatment when we talk about pretreatment for RO treatment. It is estimated from the model that the fixed cost only of 1m3 of permeate will cost about 40 cent and it's estimated from comparison study that one cubic of treated wastewater will cost around 88 cents for all stages of treatment when conventional pretreatment was employed, followed by RO membranes and this price, with UF pretreatment. This prices of course exclude the primary and secondary biological treatment of wastewater.

The energy consumption for wastewater treatment using RO as post treatment preceded by UF membrane will consume around 0.7 Kwh/m^3 without the primary and secondary biological treatment of wastewater that the will consume in average 0.45 Kwh/m^3, which is by far less than the consumption from other alternative solution as 1.7 Kwh/m^3 for brackish water desalination and up to 4 Kwh/m^3 for seawater desalination. So, comparing to the quality than can offered from RO post treatment for wastewater and in country suffers from low electricity is sound attractive solution.

Others financial benefit of reusing RO treated wastewater are the value of fresh water saved and the cost of the alternate safe disposal of the effluent to ecosystem.

Chapter 7 :
Conclusion and Recommendations

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Conclusion and Recommendations

7.1 Conclusion

- The constructed system shows high ability to remove 92.4% of TSS, 100% of BOD, 87.8% of TDS, 100% of FC and 100% of No3
- Sand filter have the ability to reduce 40% of SS which increase the ability of RO membrane to purify wastewater.
- Using other membrane types of pretreatment such as MF or UF increase the RO removal efficiency, minimize fouling and increase life of RO membranes.
- The system able to produce effluent with potable water quality for non-potable usage such as agriculture and groundwater recharging, and this quality meets the Palestinian and international standards.
- The estimated total cost for one cubic meter of reclaimed wastewater when using RO as post treatment preceded by UF pretreatment is about 88 cents.
- The main drivers for RO include the low energy consumption and the high rate of contaminant removal. It's estimated that the UF following with RO will seawater consume about (0.7) Kw h /m3 less than the power needed for brackish or seawater desalination.

7.2 Recommendations

- This study clarifies the ability of RO technology to improve wastewaters quality to meet PS standards so we recommend to build additional post RO treatment units in the current WWTPs as post treatment to use the effluent in agriculture and groundwater recharging to aquifer replenishment instead of dispose this enormous amount of water to seawater.
- The political situation in Gaza is unstable and consequently affects the donor's contribution towards developing the water sector in general and temporarily solutions becomes permanent solution. So, RO WWTPs should be part of the development plant of the Palestinian Authority until a real sensible alternative is existed on the ground.

- The consumption of power for wastewater treatment is lower than seawater or brackish water desalination, so it is a favorite solution especially in country has lack of electricity and has lack of traditional source of water.
- Further study to identify the exact cost of treatment plant and investigate economic feasibility for users.

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