The Feasibility of Reusing Treated Effluent from Rafah Wastewater Treatment Plant

M.Sc. Thesis By

Basel S. EL Hamarneh

Supervisors

Dr. Husam Al-Najar

Associate Professor of Civil Engineering

A Thesis submitted in partial Fulfillment of the requirements for the **Degree of Master** of Science in Civil Engineering - Infrastructure Program

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عمادة البحث العلمي والدراسات العليا

كـلية الــهندســــة الــمدنيـــة

ماجستير هندسة البنية التحتية

The Feasibility of Reusing Treated Effluent from Rafah Wastewater Treatment Plant

الجدوى من إعادة استخدام المياه المعالجة الناتجة عن محطة المعالجة برفح

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إقـــــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

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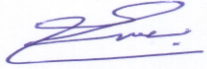
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نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة عمادة البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم

على أطروحة الباحث/ **باسل سليمان محمود الحمارنة** لنيل درجة الماجستير في كلية **الهندسة**/ قسم **الهندسة**

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The Feasibility Of Reusing Treated Effluent From Rafah Wastewater Treatment Plant

وبعد المناقشة التي تمت اليوم **السبت** 22 **جمادي الثانية** 1439هـ الموافق 2018/03/10م الساعة **العاشرة**

والنصف صباحاً، في قاعة **اجتماعات كلية الهندسة** اجتمعت لجنة الحكم على الأطروحة والمكونة من:

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وبعد المداولة أوصت اللجنة بمنح الباحث درجة الماجستير في كلية **الهندسة/قسم الهندسة المدنية/البنى**

التحتية.

واللجنة إذ تمنحه هذه الدرجة فإنها توصيه بتقوى الله تعالى ولزوم طاعته وأن يسخر علمه في خدمة دينه

ووطنه.

والله ولي التوفيق،،،

عميد البحث العلمي والدراسات العليا

أ. د. مازن إسماعيل هنية

بِسْمِ اللهِ الرَّحْمَنِ الرَّحِيمِ

قَالَ تَعَالَى :

مَّثَلُ ٱلْجَنَّةِ ٱلَّتِي وُعِدَ ٱلْمُتَّقُونَ فِيهَآ أَنْهَرٌ مِّن مَّآءٍ غَيْرِ ءَاسِنٍ وَأَنْهَرٌ مِّن لَّبَنٍ لَّمْ يَتَغَيَّرْ طَعْمُهُ وَأَنْهَرٌ مِّنْ خَمْرٍ لَّذَّةٍ لِّلشَّرِبِينَ وَأَنْهَرٌ مِّنْ عَسَلٍ مُّصَفًّى وَلَهُمْ فِيهَا مِن كُلِّ ٱلثَّمَرَتِ وَمَغْفِرَةٌ مِّن رَّبِّهِمْ كَمَنْ هُوَ خَلِدٌ فِي ٱلنَّارِ وَسُقُوا مَآءً حَمِيمًا فَقَطَّعَ أَمْعَآءَهُمْ ﴿١٥﴾

صَدَقَ اللهُ الْعَظِيمُ

Abstract

Gaza strip suffers from a serious shortage in water resources, due to the continuous increase in population, life changes, political conditions and drought caused by climate change. Due to increased demand in the Rafah governorate for water for domestic use, resulting accumulation of large quantities of wastewater in the treatment plant in Rafah, therefore reuse of treated wastewater is one of the most recently accepted approaches to save groundwater or domestic use, contributes to increase the cultivated land area and reduces the input of mineral fertilizer.

The aim of this work is to study the feasibility of treated effluent quality from Rafah Treatment Plant, in the addition, social, cultural, and environmental aspects of reusing treated wastewater.

A questionnaire was distributed to farmers investigate accepting the use treated effluent for irrigation, and a range of concentrations were tested (Physical, chemical, biological, and heavy metals), the parameters were (BOD, COD, TKN, NH_4, NO_3, P, Cd, Pb, and Cu) accounted for (110, 250, 108, 127, 0.23, 17.9 (mg/l), < 0.003, < 0.001, and 19.9 (ppb)).

The results showed the use of treated wastewater for irrigation of all social, cultural, and environmental aspect is feasible, but from a technical standpoint, Rafah Wastewater Treatment Plant needs improvement to meet Palestinian Standards, however after installing a sand filter it will be technically possible.

 The researcher found most of farmers about 80.7%, would accept using treated wastewater in irrigation, and prefer use reclaimed or purified water term more than other terms. The effluent quantities (12,000 m^3/d) from Rafah Wastewater Treatment Plant meet the required quantities for the current agricultural irrigation (10,700 m^3/d), which can be used in other wide ranges.

The study recommended that the regulatory authority and relevant organizations should consider the study results for improving the efficiency of Rafah Wastewater Treatment Plant to be appropriate with irrigation, and provide periodic monitoring systems of test quality parameters should be adopted to ensure successful, safe and long-term reuse of wastewater for irrigation, and appropriate price for the cubic meter of treated wastewater should not exceed 0.4 NIS.

Abstract in Arabic (ملخص الدراسة)

يعاني قطاع غزة من نقص حاد في امدادات المياه لأسباب عديدة تتمثل في الزيادة المستمرة في عدد السكان والتغير في نمط الحياة والأوضاع السياسية والجفاف الناتج عن التغيرات المناخية، ونتيجة لزيادة الطلب في محافظة رفح على المياه للاستخدام المنزلي مما ينتج عن ذلك تجمع كميات كبيرة من مياه الصرف الصحي في محطة المعالجة برفح، لذلك تعد إعادة استخدام مياه الصرف الصحي المعالجة حسب طرق استغلال المياه التي تحظى بقبول ملحوظ في الآونة الأخيرة، وتساهم في زيادة مساحات الأراضي المزروعة والحد من استعمال الأسمدة الزراعية.

الهدف من هذه الدراسة تقييم الجدوى لإعادة استخدام مياه الصرف الصحي الناتجة عن محطة المعالجة برفح، بالإضافة إلى دراسة الجوانب الاجتماعية والثقافية والبيئية لإعادة استخدام مياه الصرف الصحي المعالجة.

ولتقييم خيارات إعادة الاستخدام المياه المعالجة الناتجة في مجال ري المزروعات تم توزيع استبيان على المزارعين للتحقق من ذلك، وأيضاً تم الاعتماد على مجموعة من الفحوصات (الفيزيائية والكيميائية والبيولوجية والمعادن الثقيلة) للعينات المأخوذة من مياه الصرف الصحي المعالجة الناتجة عن محطة معالجة الصرف الصحي برفح وهي (BOD, COD, TKN, NH$_4$, NO$_3$, P, Cd, Pb, Cu)، وأظهرت النتائج القيم (110, 250, 108, 127, 0.23, 17.9 (mg/l), <0.003, <0.001, 19.9 (ppb).

أظهرت النتائج أن استخدام مياه الصرف الصحي المعالجة لأغراض ري المزروعات ممكن من جميع الجوانب الاجتماعية والثقافية والبيئية، ولكن من الناحية التقنية فإن محطة المعالجة برفح تحتاج إلى تطوير لكي تتوافق مياه الصرف الصحي المعالجة الناتجة عنها مع المعايير الفلسطينية ، وسيصبح ذلك ممكناً بعد تركيب مرشح رملي لمحطة المعالجة.

وجد الباحث أن أغلبية المزارعين حوالي 80.7 % يقبلون استخدام مياه الصرف الصحي المعالجة في الري، كما أن المزارعين يفضلون استخدام مصطلح المياه المستصلحة أو المنقاة لوصف مياه الصرف الصحي المعالجة أكثر من المصطلحات الأخرى، بالإضافة إلى أن الباحث وجد أن كميات مياه الصرف الصحي المعالجة الناتجة عن محطة رفح والتي تقدر بحوالي (12,000 متر مكعب/ اليوم) تفي بالكميات المطلوبة للري (10,700 متر مكعب/ اليوم) ، والتي يمكن استخدامها في نطاقات واسعة أخرى.

توصي الدراسة أن تقوم الهيئات الرقابية والمنظمات ذات العلاقة بأخذ نتائج هذه الدراسة بعين الاعتبار لتحسين كفاءة محطة المعالجة برفح بما يلائم متطلبات الري، وتوفير أنظمة مراقبة دورية لمعايير الجودة لضمان إعادة استخدام ناجحة وآمنة وطويلة الأجل لمياه الصرف الصحي المعالجة في الزراعة، بالإضافة إلى أن الدراسة توصي بأن السعر المناسب لكوب المياه المعالجة يجب ألا يتجاوز 0.4 شيقل.

Dedication

I wish to dedicate this thesis to my **father**, and **mother** for their everlasting love and

endless fervent prayers, who have supported me all the way since the beginning of

my life.

My brother: **Nouh**, who has been a great source of motivation and inspiration.

My **family**, **friends**, **colleagues** and all those who believe in the richness of learning.

Specially dedication to my friend: **Ismail Al-Zamly**, to encouragements me pursue

my education.

Also, finally, this thesis is dedicated to everyone helped me.

I love all of you so much.

Acknowledgment

First, thanks to Allah the compassionate the merciful for giving me patience and strength to accomplish this research. I would like to thank all those who have assisted, guided and supported me in my studies leading to this thesis.

I would like to express my gratitude and deepest thanks to my supervisor **Dr. Husam M. AL Najar** for his great help, guidance, encouraging support, valuable ideas.

Acknowledgement is due to the Islamic University-Gaza (IUG) for the given opportunity to pursue my graduate studies. Also, I would like to extend my thanks to Engineering Department in the IUG.

I would like to express my grateful appreciation and thanks to everyone who gave me support to bring this research to light. Especially Coastal Municipalities Water Utility (CMWU) and Ministry of Agriculture (MOA).

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Exceptional thanks to the Middle East Desalination Research Center "**MEDRC**" staff who has supported this research financially. Without this very valuable support, my work could not be in this good form realized.

Finally, my deepest appreciations are to my parent, brothers, sisters and family for their full support, encouragement, and patience that give me the power to go on.

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List of Abbreviations

APHA	American Public Health Association
APTCO	The Association of Public-Safety Communications Officials
BOD	Biochemical Oxygen Demand
Ca$_{++}$	Soluble Calcium
Cd	Cadmium
CFU/100 ml	Colony Forming Units per 100 milliliters
CIS	Commonwealth of Independent States guidelines
CL	Chloride
cm	Centimeters
cm^2	Square Meter
CMWU	Coastal Municipality Water Utilities
Co	Cobalt
COD	Chemical Oxygen Demand
Cr	Chromium
Cu	Copper
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DOP	Declaration Of Principles
µS/cm	Micro Siemens per Centimeter
dS/m	Decisiemens/meter = 1000 µS/cm
DTPA	Die Thylenetriamine Pentaacetic Acid
EC	Electrical Conductivity
EDTA	Ethylene Diamine Tetra Acetic Acid
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
FC	Fecal Coliforms
Fe	Iron
Freq.	Frequency
GS	Gaza Strip
GDP	Gross Domestic Product
HP	Horse Power

ICRC	International Committee of the Red Cross
IUG	Islamic University - Gaza
K	Potassium
KVA	Kilo-Volt-Ampere
KW	Kilowatt
L/C/D	Liters/ Person/ Day
m	Meter
m/s	Meter Per Second
m^2	Square Meter
m^3	Cubic Meter
m^3/d	Cubic Meters Per Day
m^3/h	Cubic Meters Per Hour
MCM	Million Cubic Meters
Mg	Magnesium
mg/l	Milligrams per Liter
Mg$_{++}$	Soluble Magnesium
mm	Millimeters
Mn	Manganese
mFC	Membrane Fecal Coliform
MOA	Ministry Of Agriculture
MOH	Ministry Of Health
MOR	Municipality Of Rafah
MPN/100 ml	Probable Number Per 100 milliliters
mS/cm	Mile Siemens Per Centimeter*s*
MSL	Mean sea level
Na$_+$	Soluble Sodium
NASA	National Aeronautics and Space Administration
NH$_4$	Ammonium
Ni	Nickel
NIS	New Israeli Sheqel (Currency)
NO$_3$	Nitrate
OM	Organic Matter
P	Phosphorous

Pb	Lead
PCBS	Palestinian Central Bureau Of Statistics
Perc.	Percentage
pH	Hydrogen Potential
PHG	Palestinian Hydrology Group
ppb	Parts Per Billion=0.001ppm
ppm	Parts Per million (mg/l)= 1000ppb
PS	Palestinian Standards
PVC	Polyvinyl Chloride
PWA	Palestinian Water Authority
RWW	Reclaimed Wastewater
RWWTP	Rafah Wastewater Treatment Plant
SAR	Sodium Adsorption Ratio
SCF	Save The Children Fund-UK
TDS	Total Dissolved Solids
Temp	Temperature
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TS	Total Solids
TSS	Total Suspended Solids
TWW	Treated Wastewater
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Emergency Fund
UNRWA	United Nations Relief And Works Agency
USA	United States of America
WB	West Bank
WEAP	Water Evaluation And Planning
WHO	World Health Organization
WWTP	WasteWater Treatment Plant
Zn	Zinc

Chapter One

Introduction

Chapter one

Introduction

1.1 Background

Due to certain factors, including the lack of water and the need to treat sewage to protect public health and the environment, it becomes necessary to reuse treated effluent. Recycled wastewater in urban countries is most commonly used for irrigation of agricultural land, groundwater recharge, industrial uses, landscape irrigation and increasingly, safe aquifers as sustainable drinking water sources.

The groundwater coastal aquifer is considered a vital factor of water in the Gaza Strip and gives around 98% total water supply, while the remaining 2% is given through buying from the Israeli water company MEKOROT. Because of high density of domestic wells that are pumping continuously with high pumping rates, the impact of the cone of depressions effects on groundwater, with different degree of influence, the water level decrease in Rafah areas is significantly high, reflecting the low aquifer potential and in addition its sustainable water amounts compared to the pumped quantity (PWA, 2014).

The agricultural sector consumes more than half of the total groundwater pump through more than 4000 well distributed at all regions in Gaza governorates, the remaining being used for industrial and domestic water supplies (Al-Najar et al., 2009; Foul et al., 2015).

Reusing wastewater could be the essential goal in the field of saving resources in the world; this will lead to lessening the gap about water deficiency amongst supply and demand. Moreover, this strategy is adopted by the Palestinian Water Authority.

However, using treated water in Gaza strip is considered a new phenomenon to the farmers and to all other workers in this field, since it has never been practiced in Palestine before except for some pilot studies, experiences on these issues remain vital until the reuse of treating wastewater becomes common in the coming years or decades (ÖZEROL, 2013).

Thus, the current study will attempt to assess the potential of reusing the treated effluent from Rafah wastewater treatment plant (RWWTP) in irrigation of

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agricultural land, it usually has the potential to meet growing water demands, conserve potable supplies.

1.2 Problem Identification

Mediterranean regions are characterized by serious water imbalance, this imbalance between water demands versus supply is due mainly to the limited resources and uneven distribution of precipitation, high temperatures, and expanding needs for water demand (Fatta et al., 2005). According to the Population Reference Bureau, seeing world's fastest growing populations is in the Gaza Strip, where the population growth rate is 4.5 percent a year, their demand for water is increasing (Martin, 2015). In the Gaza Strip, over 50% of freshwater consumption is devoted to agricultural activities. Over exploitation of the aquifer diminished seriously the quantity and quality of groundwater badly needed for human consumption as well as for agriculture as one of the main sources of income in the Gaza Strip. The reuse of treated wastewater could be an essential option to solve the water deficit crisis in Gaza Strip (PWA, 2015).

Irrigation using treated wastewater is considered as a priority in Rafah due to various factors, including the depletion of groundwater resources and actually, reuse would increase the available freshwater resources for domestic and industrial use, in addition the rainfall in Rafah is 250 mm/year in comparison to 450 mm/year in the north of the Gaza Strip. Moreover, agriculture is the main job for income for most of Rafah residents where the residents of Rafah have high unemployment records due to lack of water resources for agriculture.

Assuming that 80% of the water used for domestic usage returns as wastewater, the potential wastewater produced from Rafah Governorate will be more than 16,000 m^3/day of the year 2020, this situation will increase with the increase in population and the increased demand for water supply.

The wastewater that is generated in Rafah is currently discharged into the sea; a small amount infiltrates into the soil and contaminates the groundwater. The efficient treatment and reuse of such considerable quantity of wastewater in areas characterized by water crisis becomes a priority at a local and national level to meet increasing agricultural water demand, which was identified as one of the main objectives of the Palestinian water sector. However, the soil in west Rafah is

characterized by its sandy texture with high infiltration rate, irrigation by partially treated effluent could increase the input of pollutants to the groundwater. In the current research, the feasibility of using treated effluent in irrigation will be conducted considering social, environmental and cultural impacts.

1.3 Scope and Objectives

The aim of this research is to study the potential of reusing the treated effluent from Rafah wastewater treatment plant from an environmental and technical standpoint.

The objectives can be summarized in the following points:

1) Improving food security conditions through the promotion of the reuse of the produced treated wastewater for agricultural purposes.
2) Verify the accepting the use of treated wastewater for irrigation of all social, cultural, and environmental, in addition from a technical standpoint of RWWTP.
3) Investigating the farmer's desire to use treated wastewater in the Rafah governorate.
4) Study the appropriateness of the treated wastewater for various types of agricultural crops.
5) Determine the current water use in irrigation of the main agriculture land cultivated in the Rafah.

1.4 Motivations

1. The researcher is studying wastewater treatment in Rafah governorate because it is your town and researcher want to participate in solving the problems of water shortage in Rafah area.
2. The lack of a wastewater disposal system causes potential pollution to the groundwater.
3. This is a vital topic at the national level and the result of this work can be implemented in other areas in the Gaza strip.

1.5 Research Justifications

RWWTP is located in the western part of Rafah, about 500 meters near the border with Egypt. The site is surrounded by sand dunes, located in agricultural areas

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contain a wide variety of agricultural crop type (for example: vegetables, fruits, almonds, lemon, guava, olive and apple trees etc....).

Just less than 1 km located Mawasi area which is famous for agriculture, the central assembly in this region has already requested to use water treated from RWWTP for agricultural purposes.

On the other hand, the southern region of Gaza Strip characterized by high saline water for irrigation, which causes many problems for farmers, which involves finding urgent solutions and alternative sources of water. In the near future desalination plants with total capacity of 60 million m^3/year will start to provide potable water to the municipalities. As a consequence the produced treated effluent will have a low salt content. Therefore, the use of treated effluent in irrigation purposes will be feasible from the chemical quality standpoint (PWA, 2016).

1.6 Research Questions

The following are the research main questions:

1. What is the farmer's opinion in Rafah area about the use of treated wastewater in irrigation?

2. What are the factors that should be considered to accept wastewater reuse prior to implementation of wastewater reuse in rafah governorate?

3. The possibility of social acceptance of the reuse of treated wastewater in Agriculture?

4. Quantity of water needed for agriculture in the Rafah area based upon the type of crops?

5. Do the people trust the municipality will treat wastewater as well? Does this level of treatment affect accepting the use of treated wastewater for irrigation?

6. Does the term use to describe treated wastewater (reused water, treated wastewater, and reclaimed or purified water) affect accepting the use of treated wastewater for irrigation?

7. Is the level of income, and education is related to customer satisfaction with the use of treated wastewater?

8. What is the best way to raise environmental awareness in Rafah area?

1.7 Thesis Structure

The basic structure of the thesis is organized in five chapters, as follows:

Chapter One: Introduction

It provides a background on the Rafah water crisis, summary of the problem statement, Scope and Objectives, motivations to prepare study, research justifications, research questions, and structure of the research.

Chapter Two: Literature Reviews

It summarizes the literature reviews along with background information relating to wastewater reuse, and observations from the past. It is included: the importance of wastewater reuse, wastewater treatment technologies, local and global main contribution studies and reports, wastewater reuse in agriculture, benefits and risks of wastewater reuse on agriculture, and standards of treated wastewater.

Chapter Three: Study Area

The study area describes general description about population, geographically with a briefing about water demand for Rafah governorate and crisis, sewerage system in Rafah, Rafah Wastewater Treatment Plant (RWWTP), agriculture land and crop types in Rafah governorate.

Chapter Four: Methodology

The methodology of the study dived into two parts, first part collection and analysis of wastewater samples taken from RWWTP, a second part distribute a questionnaire to farmers then statistical analysis.

Chapter Five: Results and Discussions

Presents the results of tests discussed and compared with local, and international studies. Also questionnaire results are analyzed and discussed.

Chapter Six: Conclusion and Recommendations

It provides a brief summary of the research findings as a conclusion followed by future recommendations for best practices.

References: contains the basic references, which have been reviewed by the researcher.

Appendices: contains the basic tables.

Chapter Two

Literature Review

Chapter Two

Literature Review

2.1 Introduction

In recent years, there is a necessity to the wastewater reuse; treated wastewater (TWW) has importance value and non-conventional water resource, especially in the Middle East and Gaza Strip (GS). This area is experiencing the most rapid rates of population and urbanization of industrial and agricultural activities, which has made a gap in the water budget (Kayyal and Jamrah, 1999).

The current situation in the water sector in GS facing challenges are related to several factors, including the extreme scarcity of water resources, continuous growth of water demand due to population growth, economic development and rising standards of living, insufficient water supply and sanitation, inadequate tariffs, insufficient control on water consumption and excessive water losses (PWA, 2004).

2.2 Current Status of Reuse Project in the Gaza Strip

There are five basic wastewater treatment plants in GS, in addition to temporary plant (currently under construction to permanent plant), for collecting and treating wastewater treat to the level allowed to be dumped into the sea and to not pollute the aquifer in case of infiltration except for the north WWTP located in a closed depression without a natural outlet to the sea, a substantial quantity of wastewater infiltrates into the ground. WWTPs are placed along the GS (North, Gaza, Wadi Gaza, Khanyounis, and Rafah). The locations of these treatment plants were chosen during the times of the Israeli occupation of the GS. However, the regional contour of Ministry of Planning suggests establishing three central treatment plants near the eastern armistice line. The improved domestic water supply quality due to the planned desalination projects, the domestic consumption is expected to increase. Consequently, the produced wastewater will increase, leading to overflow of the current treatment plants.

One of the first start practices in the GS of using TWW in agriculture was in 2003 through "Strategy of Agricultural Water Management in the Middle East Program " funded by France and implemented by PHG, in cooperation with the Ministry of Agriculture (MoA) and the PWA (Abdo, 2008). In that's time, two areas

in GS were selected for the pilot project. The first area was Beit Lahia in the northern area of Om Al Naser village where TWW from Beit Lahia WWTP was used. The second area was in the Sheikh Ejleen area southwest of Gaza city, TWW from Gaza WWTP. Now there are existing three poilt projects for reuse wasterwater as following:

2.2.1 Beit Lahia Poilt Project

The first pilot located in Beit Lahia aims to demonstrate in the Bedouin village that uses water from the artificial lake (constituted by the effluent of treated water of the Beit Lahia).

- Fodder crops (alfalfa, Sudan grass and ray grass) irrigated and used for feeding the small animals. The total area cultivated by alfalfa is extended to 45 dunums and enlarged to 140 dunums in 2010 by Italian fund.

- A comprehensive monitoring system is also carried out to examine and detect the hygienic and environmental problem and it is extended to cover crop, soil, ground water and the effluent.

- Short training course for the farmers as well the agricultural engineers to qualify the target groups and strengthen the capacity building in PWA, MoA and NGO's besides launching public awareness for the interested farmers and agricultural associations.

- A field visit for 4 farmers to Jordan has been organized to introduce the Jordanian expertise and pilot projects funded by the French Embassy (MREA) in Jordan.

2.2.2 Sheikh Ejleen Pilot Project

- It aimed to demonstrate the interest of using treated waste water for the irrigation of citrus and olive orchards. Farmers interested in experiencing this new source of water have been contacted in the area around the Sheikh Ejleen wastewater treatment plant.

- This area is located around the Salah Eldeen road, close to the network conveying the TWW from The Gaza WWTP to the infiltration basins and wadis.

- In 2004, the job creation program (JCP) in cooperation with the Palestinian Hydrologists Group has proposed a project to use TWW from Sheikh Ejleen WWTP for irrigating 100 dunums of citrus and olive trees.
- The project has been established under French fund and the supervision of the PWA and Municipality of Gaza with coordination with the MoH and MoA. This project was relatively successful, thereafter; extension has made to the Israeli invasion in 2008, which led to the destruction of some of the infrastructure of the project. However, rehabilitation is currently done under the French and Spanish funds. This project was operated again on November 2010 covering 186 dunums.

2.2.3 Al Mawasi Pilot Project (khanyounis pilot project)

- With a fund of the Catalan Government, the Job Creation Program (JCP) in close cooperation with PWA and CMWU launched a small pilot project for reuse of treated effluent with soil aquifer treatment system.
- The project started with 60 dunums in 2008 and expanded to 90 dunums in 2010 cultivated with Guava and Palm trees. The BOD resulted from the recovery wells reaches 20-25 mg/l.

2.3 Reuse Standards of TWW

The combination of water shortages, densely populated urban areas and wide irrigated agriculture, makes many countries put reuse water on the national priority list. Globally, there isn't a similar regulation of TWW because of various geological and geographical conditions, climate, type of soils and crops, water resources, economic and social aspects, countries policy towards utilizing wastewater effluents for agriculture purposes. Some organizations and countries already have established reuse standards like United States Environmental Protection Agency, FAO, WHO, Italy, and France.

The greatest developing countries have put their own standards depend on standards set by either WHO, FAO, etc... (EPA, 2004). WHO developed guidelines for TWW to protect the environments and human health since the year 1973, after an exhaustive audit of epidemiological investigations and other data, the guidelines were refreshed in 1989 (Ensink and Hoek, 2007).

FAO guidelines explain the impacts of water saltiness, crop production, and water toxicity on the plant. Also FOA guidelines provide management tools to show enhance in the economy, environment, sustainable ways, additionally, health protection includes (consumers of agricultural products and workers in this field) (Pescod, 1992). The Israeli standards are very similar to the Palestinian standards and differences between both standards are minor, The Palestinian standards prevent irrigation of vegetables from TWW, which is the major difference between these two standard (Mizyed, 2012). Since 1959 the Israel law has clarified TWW as a part of the water resources, and guidelines for wastewater treatment were established in the seventies after an outbreak of cholera in Jerusalem because using untreated wastewater. Israel Regulations are updated continuously to reflect the discoveries from current research based on practical applications and establish a precedent for the rest of the world (Kellis et al., 2013).

Different countries namely (United Arab Emirates, Oman, Saudi Arabia, and Kuwait have adopted stringent health reuse guidelines similar to those employed in some USA states (e.g., fecal Coliforms less than 2.2 MPN/100ml), while some do not have any sort of regulatory guidelines (EUWI, 2007).

2.4 Palestinian Standards

Palestinian Standard (PS) for the TWW (PS 742/2003) which has been established by the Palestinian Ministry of the Environment and authorized by Palestinian Standards Institute, after the establishment of Palestinian law in 1999, which states in (Article 29): "The Ministry of Environmental Affairs (MENA), in a joint effort with the capable agencies, shall set guidelines and standards for gathering, reusing, treating, or arranging wastewater and tempest water in a sound way, which agree to the protection of the earth and general wellbeing" (EQA, 1999).

The existing four WWTPs (Beit Lahia, Gaza, Wadi Gaza, KhanYunis, and Rafah) are heavily overloaded, because of the rapid population growth. Despite the quality of the effluent from Gaza and even Beit Lahia WWTPs would nearly meet class C standards which are progressively match irrigating olives, citrus, and fodder crops (Hidalgo et al., 2005), at present, most of the effluent discharged in GS is disposed into the Sea.

TWW does not mean risk-free, different qualities of TWW exist; Tables (2.1) and Table (2.2) presents the classification of the TWW, present the effluent limitations value for conventional and unconventional pollutants according to the Palestinian standards for reuse (PS 742/2003).

Table (2.1): Classification of effluent quality (PS 742/2003)

Class		Water Quality Parameters		
		BOD_5	TSS (mg/l)	Fecal coliform MPN /100ml
Class A	High quality	20	30	Less than 200
Class B	Good quality	20	30	Less than 1000
Class C	Medium quality	40	50	Less than 1000
Class D	Low quality	60	90	Less than 1000

Table (2.2): Limitation values for effluent reuse (PS 742/2003)

NO.	Criteria	Unit	Value
1	BOD_5	(mg/l)	45-60
2	COD	(mg/l)	150-200
3	NH_4	(mg/l)	NA
4	TKN	(mg/l)	50
5	NO_3	(mg/l)	50
6	P	(mg/l)	30
7	Na_+	(mg/l)	460
8	Ca_{++}	(mg/l)	400
9	Mg_{++}	(mg/l)	60
10	Cl	(mg/l)	500
11	SAR	meq/l	9
12	TSS	(mg/l)	50
13	FC	CFU/100 ml	<1000/100ml
14	TDS	(mg/l)	1500
15	pH	Value	6-9
16	EC	µs/cm	2500
17	Cd	(mg/l)	0.01

NO.	Criteria	Unit	Value
18	Pb	(mg/l)	0.1
19	Cu	(mg/l)	0.2

* PS-742/2003 for dry fodder irrigation.
NA: cannot give a relevant

2.5 Reuse in Neighbouring Countries

Several neighbouring countries (Israel, Jordan, Egypt, and Tunisia) have water management strategies, which consider wastewater as a vital water asset and furthermore executed measures accordingly.

Some countries allow reuse of TWW in restricted irrigation, for example Egypt does not permit using TWW in crops valid for human consumption, but in Israel, unrestricted irrigation is permitted only when using advanced treatment.

Between Arab-countries, Jordan is considered the most advanced country in the field of reusing wastewater that not only apply effluent criteria, but also has a set up a crop monitoring system for the Jordan Valley and also have procedure for a better cooperation amongst responsible authorities. The competition is an integral for reuse TWW, because limited water resources, especially with an overpopulation, which gives a continuous significant supply of TWW (Zidan and Dawoud, 2013). Wastewater reuse is generally linked with health and environmental risks. As a consequence, its acceptability to replace other normal water resources for irrigation is extremely subject to if the health threats and environmental influences entailed are acceptable or not (Angelakis and Bontoux, 1999).

Jordan reuses 85 present of the wastewater generated in the country, Israel and Tunisia reuse 67 and 20 present respectively (Petousi, 2015). Egypt and the Palestinian National Authority reuse smaller proportions. Each of the five countries, however, maintains its own regulations and standards for the use of TWW and other sources of marginal water. These different regulatory environments were compared in a concept note after the Initiative's Granada Workshop in October 2002.

Farmers in developing countries irrigate with wastewater due to the availability of nutrients, limited availability of freshwater, and lower cost in comparison to using fresh drinking water (Sato et al., 2013).

In fact, there is not enough literature developed around the best practice, but it was restricted to project publications.

In addition, the wastewater reuse potential in the Middle East and North Africa countries is very high due to extreme water scarcity. There are at least ten countries in the region that have the largest volume of wastewater used for irrigation.

Egypt, Jordan and Tunisia are considered from the top ten Arab countries largest amounts of wastewater used in irrigation, Egypt ranked first with an estimated quantity achieve 1,918,000 m^3/day, while Jordan ranked sixth in the amount of 240,000 m^3/day, Tunisia ranked eighth with a quantity of 118,000 m^3/day (Jimenez and Asano, 2008).

2.5.1 Egypt

Use of treated and untreated water in irrigation go back at the Elgabal Elasfar farm, since 1911, and has been practiced historically in Egypt. This farm was in the beginning set up for forest development, and it's been developed in crop production and citrus. Although the grade of the irrigation water currently applied fitth's acceptable levels, sustainable management strategies recommend monitoring the degrees of heavy metals in the soil and executing appropriate remediation programs due to the historical use of untreated wastewater as of this farm (Elbana et al., 2013). Moreover, the lack of sanitation systems in rural Nile delta drives farmers to release wastewater into agricultural drains; this is a common, unofficial practice (Agha et al., 2011). Therefore, wastewater treatment is necessary in the Nile delta area. Decentralized wastewater treatment in densely filled rural region areas such as the Nile delta, with appropriate cluster size, is preferred because it would provide conditions favorable for reusing TWW (Shafy and Mansour, 2013; Soliman et al., 2009).

TWW provides an unconventional water source for irrigation in Egypt (Elbana et al., 2014). A significant volume of drainage water is often pumped and used for irrigating plants, especially through the summer months when water in the irrigation canals is decreed level. The Ministry of Water Resources and Irrigation in Egypt MWRI (2005) has clarified that TWW would be mainly utilized for greenbelt and non-food agricultural development predicated on several factors, including: treatment type and level, costs, the balance of the source and demand, irrigation method, environmental impact, cropping pattern, and availability of cultivation area. Due to water scarcity become the reuse of agricultural drainage water is a common practice

in Egypt. A few of these agricultural drains become major carriers of untreated wastewater which that are subsequently used for irrigation (Gamal et al., 2005).

Where Table (2.3) shows the quantities of gathering and TWW for different Egyptian governors, relating to a report in period (2014 - 2015) that was completed by the Central Agency for Public Mobilization and Statistics in Egypt (CAPMAS, 2016).

Table (2.3): Quantities of gathering and TWW for different Egyptian governors, relating to a report in period (2014 - 2015)

Governorate	Collected Wastewater	Total TWW	Treatment		
			Primary	Secondary	Tertiary
	$\times 10^6 \text{ m}^3$				
Cairo	1,436.1	1,263.1	-	1,248.5	14.6
Alexandria	576.0	445.4	140.7	304.7	-
Menia	47.9	44.5	0.8	44.0	-
Suez	133.7	76.1	-	76.1	-
Darmietta	98.7	94.5	-	94.5	-
EL-Beheira	99.6	81.7	-	81.7	-
AL Gharbia	188.8	156.1	-	156.1	-
Sharqeia	118.9	95.0	-	95.0	-
Port-Said	152.7	73.8	-	73.8	-
Kalyobiya	71.0	55.1	-	55.1	-
Monufia	123.6	87.2	14.2	73.0	-
Faiyum	73.9	40.9	-	40.9	-
Kafr EL Sheikh	79.7	72.8	-	72.8	-
Dakahila	326.5	184.0	-	184.0	-
Giza	1,070.4	660.3	438.0	174.8	47.5
Bani Souwaif	40.5	40.5	-	40.5	-
Aswan	58.3	27.7	18.7	9.0	-
South Sinai	14.1	9.3	3.0	6.3	-
Assiut	42.9	36.0	-	30.5	5.5
Sohage	42.3	33.9	-	33.9	-
The Red Sea	7.3	5.0	5.0	-	-
Matrouh	3.3	3.3	-	3.3	-
Luxor	22.6	21.8	-	21.8	-
Qena	42.8	20.3	8.8	11.5	-
North Sinai	16.4	16.4	0.2	16.2	-
Ismailia	128.7	89.8	-	89.8	-
EL Wadi EL Gidid	32.0	19.7	1.3	18.4	-
Total	5,048.7	3,754.2	630.7	3,056.2	67.6

The total gathered wastewater in 2014–2015 was $5,048 \times 10^6 \, \text{m}^3$, and the total TWW represented 74.4% of the collected wastewater. The primary, secondary, and tertiary- TWW represented 16.8%, 81.4%, and 1.8% of the total TWW, respectively. Additionally, the collected quantities from Giza, Alexandria, and Cairo governorates represented for more than 60% of the total wastewater collected during (2014–2015) (CAPMAS, 2016).

Another example of TWW use is when the Ministry of State for Environmental Affairs, in cooperation with the United States Agency for International Development, evaluated the safe reuse of TWW to irrigate different crops in the Luxor governorate (such as: flowers, jojoba, jatropha, flax, sorghum). This evaluation endorsed using drip irrigation techniques and implementing natural resource monitoring in the project area as well as conducting risk reduction measures for protecting the workers involved (IRG, 2008). Jatropha is a bio-oil crop cultivated in Egypt since the late 1990s using TWW. Recently, its cultivated area has spread to over 2,000 feddan, it is planted mainly in Upper Egypt governorates and has promising economic potential (Soliman, 2015).

2.5.2 Tunisia

Since 1965, Tunisia has long experience in utilizing TWW to irrigate the olive trees and citrus orchards of the Soukra irrigation project (North East of Tunisia) covering a location of 600 hectares (Bahri, 2008). The Government in Tunisia support management and environmental pollution control since 1975 and gives high top priority to wastewater reuse as it is an important measure to protect freshwater resources for drinking purposes. Reclaimed wastewater (RWW) use in irrigation has been a part of the Government's overall water resources (World Bank, 2010). The legal framework (Water law) provides a good basis for wastewater reuse, but requires further explanations and amendments. Existing quality standards aren't enforced due to a lack of treatment capacity.

The existing rate of reuse is approximately 29%, reused for the cultivation of cereals, fruit trees, fodder crops and industrial crops as well as for golf courses and green spaces. Wastewater is also reused in the conservation of wetlands and recharges purposes (Slimi and Kamoun, 2006).

Within 2008, the number of wastewater treatment plants working in Tunisia were sixty-one, collecting 0.24 billion km³ of wastewater, of which less than thirty percent is reused to irrigate citrus, vineyards, trees (apples, peaches, pomegranates, pears, olives) fodder vegetation (sorghum, alfalfa), commercial vegetation (tobacco, cereals, and cotton) (Chenini, 2008). The wastewater effluent is treated to secondary levels and farmers pay support charges for irrigating their fields from TWW (Bahri, 2008).

2.5.3 Jordan

Jordan has twenty-two wastewater treatment plants treating around 90 million m^3/year (ACWUA, 2010), treatment plants are located in large cities, but do serve extensive ranges surrounding these cities. All effluents from treatment plants are either specifically utilized for irrigation or are stored first in reservoirs/dams that are used for irrigation. The Ministry of Water and Irrigation forecasts that the amount of TWW used for irrigation will achieve 223 million m^3 by 2020 (Lange et al., 2010).

Since 2002, the Jordanian government, with the support of international organizations, has been implementing several direct water reuse activities in Wadi Musa and Aqaba whose aim is to demonstrate that reclaimed water reuse can be safe, commercially practical, environmentally sustainable, socially acceptable, and reliable.

The Wadi Musa pilot farm project near to the ancient city of Petra uses the treated effluent of the Petra Regional Wastewater Treatment plant to grow a variety of agricultural crops, including: Sudan grass tree, sunflowers, almond, date palms, olives, lemons, poplars, pistachio, junipers, and spruce, and many varieties of ornamental flowers (daisies, petunias, geraniums, and iris).

Wastewater has been used for irrigation in Jordan for many decades. The addition of wastewater reuse in National Water Strategy for the country since 1998 was a signal of placing high priority on the value of reclaimed water. Wastewater represents 10% of Jordan's total water supply and up to 85% of its TWW is being reused (WaDImena, 2008; EUWI, 2007). It should be observed however that TWW is blended with fresh water and then used for unrestricted irrigation in the Jordan Valley.

In 2009, the new National Water Strategy was published. To help expand support wastewater reuse in irrigation, the 2008 - 2022 plan proposes, among others, to:

- Design and carry out programs on general public and farmer's consciousness to market the reuse of care for wastewater, ways of irrigation, and handling of produce.

- Ensure that health standards for farm workers as well as consumers are reinforced and that all TWW from all municipal or industrial wastewater treatment plants meets relevant national standards and is monitored regularly.

- Manage TWW as a perennial water source which shall be an integral part of the national water budget.

- Periodically analyze and monitor all crops irrigated with TWW or mixed water.

- Introduce appropriate water tariffs and incentives in order to promote water efficiency in irrigation and higher economic returns for irrigated agricultural products.

2.5.4 Israel

Israel was a pioneer in the development of wastewater reuse practices (Angelakis and Bontoux, 1999). It has achieved some impressive accomplishments in reclamation and reuse of wastewater, and at solving issues, which arose from using RWW.

About 90% of the raw sewage is treated at wastewater treatment plants and 65% to 70% of the TWW is reused. The majority of this TWW is used for irrigation in agriculture and the others can be used for industry and environmental purposes, such as increasing river flow volume, and for fire suppression (Nadav, 2017), making it the leading nation in water recycling, according to an article in The Tower Magazine.

Until 1985, most reused wastewaters in Israel had been used for irrigation of (cotton, dry fodder seeds, forest) which required minimum effluent quality, due to the short irrigation season of cotton (less than 90 days), found a recipient (the agricultural sectors) who willingly accepted minimally treated effluents. As cotton prices in world markets have sharply decreased since 1985. The farmers demanded

wider crop rotation to include highly profitable vegetables and fruits aimed not only at the local market, but also for export (Shelef, 1991).

2.6 Wastewater Treatment Technologies

In any system mean for reusing water ensuring public health is necessary. Human being in contact with disease-causing microorganisms or different contaminants in treating effluent may lead to serious public health problems. Here, wastewater that could come from contact with the public is treated at the tertiary level, which almost eliminates almost the original contaminants.

Different strategies for wastewater treatment have been utilized as a part of the countries over the previous decades, a large group of new advancements is being created and wide, response to societal limitations, economic and environmental restrictions ever more posed by conventional wastewater systems. New methods incorporate natural techniques and are designed with sustainability in mind, as opposed to energy-intensive and chemical-dependent systems in current use.

To make the product water suitable for reuse or discharge, influent wastewater is routed through a set of unit processes through which impurities are removed. Treatment is divided into four general stages: preliminary, primary, secondary, and tertiary (or advanced). Depending on the desired characteristics of the target water and treatment goals, unit techniques can be selectively employed. Table (2.4) summarizes the goals and typical operations of each level. After treatment process using disinfection is to substantially decrease the amount of microorganisms in the water to be discharged back into the environment.

The effectiveness of disinfection depends on the grade of this inflatable water being treated, the type of disinfection being used, the disinfectant dosage (time and concentration), and other environmental factors. The most popular disinfectants used to remove pathogenic organisms are ozone, ultraviolet light, and chlorine.

Table (2.4): Information about treatment technologies used in every stage

Treatment stages	Purpose	Technologies
Preliminary	Removal of large solids and grit particles	Screening, settling

Treatment stages	Purpose	Technologies
Primary	Removal of suspended solids	Screening, sedimentation
Secondary	Biological treatment and removal of common biodegradable organic pollutants	Percolating or trickling filter, anaerobic treatment, activated sludge, waste stabilization ponds (oxidation ponds)
Tertiary (or advanced)	Removal of specific pollutants, such as nitrogen, color, odor, etc...	Sand filtration, membrane bioreactor, reverse osmosis, ozone treatment, chemical coagulation, activated carbon, disinfection.

2.6.1 Primary Treatment

Generally selected to eliminate floating materials and settleable solids present in the wastewater, it is the minimum level of pre-application treatment required for wastewater, really is considered sufficient treatment if the wastewater is used to irrigate plants that aren't eatable and could be sufficient treatment for irrigation of some orchards (Pettygrove and Asano, 1984).

2.6.2 Secondary Treatment

Secondary treatment refers to those treatment processes that use biological processes to convert dissolved suspended, and colloidal organic wastes to more stable solids that can either be removed by settling or discharged to the environment without causing harm. Secondary treatment is a direct process towards the removal of biodegradable organics and suspended solids. Biological treatment systems are designed to maintain a large active mass of bacteria within the system. It is the level of pre-application treatment required when the risk of public exposure to wastewater is moderate (Pettygrove and Asano, 1984).

2.6.3 Tertiary Treatment (advanced treatment)

The goal of tertiary treatment is to give a final treatment stage to improve the effluent quality before it is discharged to the receiving environment (sea, ground, lake, river, etc...), it is important to add disinfection at the final stage of tertiary treatment processes called "effluent polishing".

2.7 Reasons for wastewater reuse

2.7.1 Environmental Benefits

Water reuse to recharge aquifers can help in meeting good quantitative status and avoiding deterioration in the status of groundwater if it can be ensured that the chemical status is not adversely affected. Water reuse can increase the natural and the artificial flow in streams and ponds, which meets the quantitative objectives of surface water bodies. Restoration of streams, wetlands and ponds using water reuse has been found to be effective in some cases, leading to the revival of aquatic ecosystems.

In water-scarce areas, water reuse provide an alternative source, thus enhancing the availability of water and the stability of the water supply. In some cases, using TWW, reduce the need for artificial fertilizers by providing nutrients for crops.

The aesthetic improvement of urban conditions and recreational activities through means of irrigation and fertilization of green spaces such as sports facilities, parks and gardens.

Planned water reuse reduces the risks to the environment and human health that can be created by unplanned reuse.

2.7.2 Economic Benefits

According to CIS (2016), there are important economic benefits for many reasons such as:

- Water is a resource. As such avoiding the loss of that resource can deliver economic benefits.
- Water reuse can have a positive impact on land value, as it may allow land located in water stressed areas to be developed. When used for irrigation, water reuse can encourage more productive agriculture.
- Water reuse may encourage a more appropriate pricing of water, which in turn could create incentives to reduce water demand.
- The water reuse sector can develop an innovative and dynamic water reuse industry with expanded competitiveness and can stimulate innovation.

2.7.3 Social Benefits

The CIS (2016) guidelines on integrating water reuse in water management identified several of the key potential benefits as follows:

- The increased economic activities made possible with water reuse would in turn lead to social benefits such as employment. In particular, for countries with important tourism industries, water reuse would indirectly support the development of tourism by allowing the development of water-related activities such as golf courses, parks or hotels.

- Water reuse could improve food security by providing an alternative source for irrigation and in turn support rural communities and businesses.

- Water reuse could also encourage a more integrated approach to water management, considering both drinking water and wastewater together.

2.8 Impacts of Wastewater Reuse

Random use of wastewater in the agricultural sector has important negative effects on the health implications for product consumers, farmers, and surrounding areas. Raw or partially TWW has been applied in many locations across the world not without creating serious public health effects and negative environmental influences. This made the existence of endemic and quite epidemic diseases (Kamizoulis, 2004).

2.9 Health Impact and Environment Safety

Water reuse presents environmental, economic and social benefits but also potential drawbacks. The risks presented by wastewater reuse have to be addressed in order to ensure health and environmental security. The CIS (2016) guidelines on integrating water reuse in water management identified several of the key potential benefits and risks to address in order to engage in safe water reuse, these are summarized below (CIS, 2016).

Untreated wastewater contains polluting substances and organisms that can pose a risk for both environment and human health. The presence of these substances and organisms is reduced through treatment, in particular secondary treatment, but additional treatment may be necessary to provide water safe for reuse. Some of the substances are already regulated under European Parliament legislation, and it is important that water used for reuse does not lead to the non-implementation of this legislation.

If water has not been appropriately treated before being reused, both the environment and human can be contacted with pathogens and chemicals through

spraying during irrigation, direct contact with the water or the consumption of unwashed/uncooked crops on which the pathogens might occur. Through time, chemicals can accumulate in the soils or infiltration into groundwater that's lead to environmental deterioration.

While treatment and the appropriate management of water can provide safe water to reuse, it is important to understand and assess the risk to ensure the safety of the population and the environment. Substances that may be present in water are very heterogeneous with different retention, depletion and behavior when infiltrating the soil. Some substances are more persistent than others and for some substances (including micro-pollutants) there is much that remains unknown about the health and environmental risks.

In order to control risks posed by water reuse, and quality of the TWW, factors such as: quality of the receiving water, depth of the water table (for aquifer recharge) and soil drainage (for irrigation) should be considered.

Reuse may be beneficial in terms of preventing secondary effluent discharges to the environment. However, it is also important to consider whether the discharges were contributing to maintaining flows of water bodies to avoid unexpected negative impacts on the environment.

Where reclaimed water is disinfected with chlorine, a potential negative effect of water reuse is the discharge of residues from the chlorine treatment into the environment, which may harm aquatic systems.

2.9.1 Economic Risks

Water reuse is seen as a costly option with low returns on investment in particular when compared to abstraction from water bodies. Many schemes have benefited from direct or indirect subsidy to support the supply and demand of water reuse, which may need further consideration, in particular when considering the need for cost recovery and financial sustainability in the water sector. However, it is important to notice that the cost of conventional water resources is often also subsidised or kept low (especially for irrigation). The infrastructure costs for a reuse scheme, including treatment works, water distribution systems and irrigation systems may need financing and the economic viability of such projects will depend on the specific situation.

2.9.2 Social Risks

In some countries, the public perception of water reuse can be negative and there may be a distrust of water reuse practices.

2.9.3 Categories of Wastewater Reuse

Water is a renewable resource within the hydrological cycle. The water recycled by natural systems provides a clean and safe resource which is then destroyed by different degrees of pollution depending on how, and to what extent, it is used. However, water can be recovered and utilized again for various beneficial uses. The basic types of reuse are suggested according to (EPA, 2004) shown in Table (2.5) and described in more details below:

- o **Urban reuse**: In urban areas, TWW has been used mainly for non-potable applications (Crook et al., 1992), such as: the irrigation of public parks, school yards, highway medians, and residential landscapes, as well as for fire protection and toilet flushing in commercial and industrial buildings (Tejada et al., 2015).

- o **Agricultural reuse:** irrigation of nonfood crops, such as fiber and fodder, pasture lands and commercial nurseries. High-quality reclaimed water is used to irrigate food crops.

- o **Recreational impounds**: such as lakes and ponds.

- o **Industrial reuse:** The most common uses of reclaimed water by industry are a process water-cooling tower and irrigation of grounds surrounding the industrial plant.

- o **Environmental reuse:** sustaining stream flows, enhancing natural wetlands, and creating artificial wetlands.

Table (2.5): Categories of TWW and monitoring requirement (EPA, 2004)

USE Category	Monitoring requirement
Urban reuse: food crops not commercially processed	Weekly: BOD and PH Daily: coliform Continuous: turbidity, CL_2 residue
Restricted access area: agricultural reuse: nonfood crops: food crops commercially processed	Weekly: pH and BOD Daily: Coliform, TSS Continuous: CL_2 residue

USE Category	Monitoring requirement
Recreational impoundments	Weekly: pH Daily: TSS, coliform Continuous: CL_2 residue
Landscape impoundments	Weekly: BOD and pH Daily: Coliform, TSS Continuous: CL_2 residue
Industrial reuse: cooling water	Weekly: pH and BOD Daily: TSS, coliform Continuous: CL_2 residue
Environmental reuse (steam augmentation, wetlands)	Weekly: BOD Daily: TSS, coliform Continuous: CL_2 residue
Groundwater recharge	Depends on treatment and use

2.10 Soils and Vegetation Relationships

2.10.1 Soil Resources

Influence from wastewater on agricultural soil, is mainly due to the presence of high nutrient contents (Phosphorus and Nitrogen), high total dissolved solids and other constituents such as heavy metals, which have accumulated in the soil over time. Wastewater can also contain salts that may accumulate in the root zone with possible dangerous impacts on soil health and crop yields. The leaching of these salts below the root zone may cause soil and groundwater pollution (Hussain et al., 2002).

Effects of TWW on soil depend not only on the chemical and physical properties of soil, but also on crop type as well as quality and quantity of irrigated water. Najafi et al. (2003) indicated that the only accurate method to determine the impact of wastewater on soil is to measure the soil characteristics and monitor them along the time and to compare the similar soil irrigated under similar condition using fresh water.

Soil-related impacts of wastewater can be grouped under the following:

(1) Potential yield losses.

(2) Cost of additional nutrients and soil enhancement measures (WHO, 2006).

(3) Depreciation in market value of land.

(4) Loss of soil productive capacity.

2.10.2 Soil Salinity

Soil salinity is induced by several factors. Soils may become saline as a result of land use, like the use of irrigation water with high degrees of salt. Seawater is also a way to obtain salts, irrigating from salt-impacted wells or saline industrial water may lead to the forming of saline soils.

Although saline soil can produce acceptable yields, excessively saline irrigation water leads to reduced water available for plant use, which in turn can result in lower stem diameter and consequently, lower fruit yield. A growing crop has a basic demand for water to produce the maximum yield. Salinity also has an impact on soil water availability, decreasing its availability to the crop in proportion to its salinity.

Kathijotes (2003) pointed out that TWW demonstrated better results in comparison to fresh farm water related to salinity. He also pointed out that salinity risk is less at the soil surface and the root zone and increases soon after this zone.

This is considered as positive as it is not expected to influence soil permeability at the surface or the plant itself (Kathijotes, 2003).

Soil to be able order to compensate for the salt accumulation, irrigation with highly saline water requires larger and more frequent applications than irrigated with good quality water (Burt and Isbell 2005). If the water management, as locally applied, accomplishes more leaching than the guidelines have assumed, salts will not accumulate as great an extent, and slightly higher salinity in the irrigation water could be tolerated. If leaching is less, salts will accumulate to a greater extent and salinity problems and yield reductions may be experienced at lower water salinity than the guidelines (Ayers and westcot, 1985). Kathijotes (2003) pointed out that TWW applied as irrigation to soils for the number of years irrigated, raises the EC to very high levels, in comparison to soils irrigated with normal fresh water. The samples irrigated with TWW, the EC values range between 1.86 mS/cm at the surface layer to 11.77 mS/cm at the bottom zone. The soil irrigated with fresh water, showing minimum and maximum values ranging from 0.5 to 0.675 mS/cm (Kathijotes, 2003).

There isn't a salinity problem is expected for waters having an EC <0.7 dS/m. But waters in the 0.7 – 3 dS/m range (slight to moderate salinity) may require

practices if full production is to be achieved. Waters with EC >3 dS/m requires very intense and careful management to control salinity, including such drastic steps as changing to a more salt to tolerant crop or greatly increasing leaching fraction (Pettygrove and Asano, 1984).

Several authors have studied the effects of RWW irrigation on the soil chemical and physical properties; including soil salinity problems (Abedi-koupi et al., 2006; Aiello et al., 2007; Rusan et al., 2007; Jalali et al., 2008; Kiziloglu et al., 2008; Abu Nada, 2009; Al-Shdiefat et al., 2009; Lado and Ben-Hur, 2009; Duan et al., 2010; Galavi et al., 2010; Klay et al., 2010; Surdyk et al., 2010; Mojiri, 2011; Coronado et al., 2011). Although the differing conditions of the previous studies such as period of RWW application, RWW quality and crop types, but the results in these field studies indicated increasing of soil salinity which irrigated with RWW as a function with time than control unit (soil irrigated with water well).

Irrigation with treated municipal wastewater is considered an environmentally sound wastewater disposal practice compared to its direct disposal to the surface or ground water bodies. In addition, wastewater is a valuable source of plant nutrients and organic matter needed for maintaining fertility and productivity levels of the soil (Rusan et al., 2007).

2.10.3 Soil pH

The pH of the soil is a measuring acidity. It indicates how sour or sweet the soil, the pH scale ranges from zero to fourteen (0 - 14), where 7 are neutral, and values below 7 indicate an acid soil, and above 7, alkaline. Because the pH scale is logarithmic, a pH change by 1 unit means it is 10 times more acidic or alkaline.

Generally, pH values in soil irrigated with wastewater are always less than that for non-wastewater irrigation due to high organic matter content (Kiziloglu, 2007; Oron, 1999).

Plant absorption of ions from the soil to obtain essential nutrients could result in a nutrient deficiency in an increase in pH due to increased alkalinity, as some ions could be unavailable at a higher pH. The reason for this is that soil pH affects the availability of nutrients within the soil and plants have different nutrient needs. Sodic soils have nutrient limitations and are deficient in zinc, iron, phosphorus and occasionally calcium, potassium and magnesium. The organic matter added through

irrigation with wastewater could help improve soil conditions by increasing its fertility and water holding capacity (Bazza, 2003).

2.10.4 Soil Sodicity

In addition to their effects on the plant, sodium salts in irrigation water may affect soil structure and reduce the rate at which water moves into the soil as well as reduce soil aerotion. If the infiltration rate is greatly reduced, it may be impossible to supply the crop or landscape plant with enough water for good growth (Pettygrove and Asano, 1984). Figure (2.1) represents the relation between salinity and sodicity of soil (FAO, 1992).

High sodium in the irrigation water can cause a soil permeability problem. Meeting the crop water demand under these conditions may become extremely difficult. In addition, other problems such as crop germination, soil aeration, disease and weed control due to surface water ponding and stagnation may need special consideration (Ayers and Wescots, 1985). The most reliable index of the sodium hazard of irrigation water is the sodium adsorption ratio (SAR) according to the equation:

$$SAR = \frac{Na}{\sqrt{\dfrac{Ca + Mg}{2}}}$$

On the other hand, significant differences between TWW and fresh water use also have been observed by SAR, and EC values by Palacios as wastewater always higher than fresh water (Palacios, 2000).
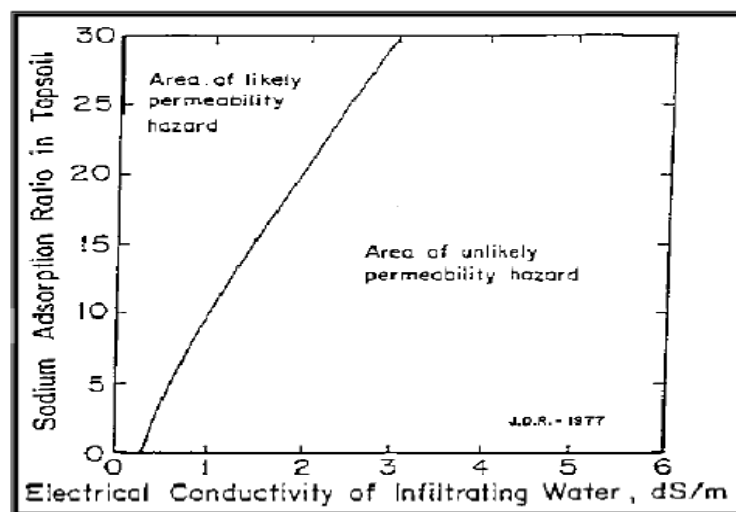
Figure (2.1): Threshold values of sodium adsorption ratio and total salt concentration on soil permeability hazard (FAO, 1992)

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2.10.5 Soil Toxicity

Agricultural soil contamination with heavy metals through the repeated use of untreated or poorly TWW from industrial establishments and application of chemical fertilizers and pesticides is one of the most severe ecological problems. Wastewater from industries or other sources carry appreciable amounts of toxic heavy metals such as: Cu, Cd, Cr, Zn, Ni, Mn, and Pb in surface soil, which create a problem for safe rational utilization of agricultural soil (Rahman et al., 2012). The most widespread toxicity from the utilization of RWW is from boron. The source of boron is usually home detergents or factories. Chloride and sodium can also increase during domestic usage, especially where water softeners are used (Pettygrove and Asano, 1984), these results agree with that obtained by El-Arabi (2006) as it was stated that the use of sewage effluent from the Ismailiya treatment plant for irrigation increased the heavy metals concentration (Fe, Zn, Cu, Pb) compared with the Nile water, however the obtained level were lower than the maximum permissible limits and the normal ranges (El-Arabi, 2006).

The study Karanja et al. (2010) has shown that accumulation of heavy metals in wastewater, lead to accumulate in soil and finally in crops. It has been demonstrated that the major source of contamination comes from industrial effluent discharges which invariably find their usage into agricultural crops.

2.11 Local and Global Main Contribution Studies and Reports

Several studies and projects for wastewater serve public health of humans and acceptable water balance, the majority of studies targets integrate economic, social and environmental aspects, but the majority of the studies and designs have yet to be realized in practice. The following briefly summarizes the principal aspects of the previous studies relevant to the current study:

☐ **Study the construction of wastewater treatment unit for irrigation purpose only (slow sand filter at RWWTP) (August /2017).**

This study will be implemented in the near future, study prepared by Global Vision Consultants (GVC), provide initial design to development slow sand filter at RWWTP, funded by Japan program (JPF). The task aims to improve access to irrigation water for farmers by using TWW for irrigation purposes only, which research gives preliminary design plans and technical specification for the

wastewater treatment unit (Slow Sand Filter) with the capacity of 3600 m^3/day. Table (2.6) shows expected effluent quality from sand filter.

Table (2.6): Expected Effluent Quality from the sand filter proposed at RWWTP to enhance WW treatment

Parameter	Effluent of RWWTP	Effluent of sand filter	Palestinian Standard
BOD (mg/l)	110	45-60	45-60
TSS (mg/l)	137	20	40-50
TKN (mg/l)	107.7	75	100
FC (CFU/100ml)	620,000	200	200
TDS (mg/l)	2976	1700-1900	1100
Chloride (mg/l)	786	786	500

 Study evaluation of environmental performance of Rafah city wastewater treatment plant and effluent reuse potential, Afifi (December/2016).

Samples were collected in wet and dry seasons (winter and spring) for one week lounge for each season from different sampling locations. The related field and laboratory parameters were performed using the facility of Environmental and Earth Science Department (EESD) and Environmental and Rural Research Center (ERRC) at the Islamic University of Gaza, to evaluate and assess the system performance in term of removal efficiency for the RWWTP system. Study differentiate the factors leading to the inadequate performance of the RWWTP and evaluate the effluent quality for reuse. The efficiencies of the different stages of the treatment and the global performance have been compared.

Collection and analysis of data showed that the system removed 67%, 60%, 78%, 37% of the influent TSS, BOD5, COD and TKN respectively with an effluent concentration of 95 mg/l, 187 mg/l, 348 mg/l, and 106 mg/l. The factors leading to inadequate treatment system performance are the over loadings, limitation of unavailability DO, inadequate design and limited electricity supply.

The biological and organic contaminants in addition to salinity and sodicity in term of SAR of the effluent were used to evaluate the reuse options in agriculture. The high level of different contaminants in the effluent limited the reuse options of the reclaimed wastewater based on the recommended PS for Irrigation.

☐ **Systems and process assessment for Rafah wastewater treatment plant in GS-Recommendation Report** (ICRC, 2013)**.**

This report described the findings of the phase II for systems and process assessment for Rafah wastewater treatment plant in GS, which was supported by ICRC and was carried out by: BG Ingénieurs Conseils, Consultants from Geneva. The phase II aimed at defining solutions for the improvement of the performances of the existing system in order to comply with different criteria for reuse of TWW. The main conclusions of this study are:

1. Highlighting the different standards for the reuse of water that can induce important variations in the dimensions of the process.
2. Proposing improvement in the definition of clear frameworks for upgrading Rafah wastewater treatment plant.
3. Showing that, in the eventuality of an upgrade of the WWTP and of the implementation of an additional wastewater treatment process, the construction of the 3rd biotower is not relevant.
4. Suggesting the most adapted processes to meet the standards is likely to be the implementation of an activated sludge.

☐ **Pre-feasibility study for a reused water distribution system in Rafah and sludge treatment facility for Gaza Governorate (1999).**

This pre-feasibility study was carried out by Dessau-Soprin and Stratem in 1999, funded by APTCO (the world's oldest and largest organization of public safety) and the Quebec Government. The objective was to determine how the construction and operation of an effluent reuse system in the area of Rafah and Khanyounis and of a regional sludge treatment plant in Gaza could be undertaken under a private investment concept.

☐ **Feasibility study of wastewater treatment plant for North Gaza.**

The study, supported by the Swedish Government, was completed by Montgomery Watson under the storm water and sewerage project in Northern Gaza, and was completed in 1999. The WWTP site located at south eastern part of the Northern Governorate, near to the Green Line. The design of a new WWTP was developed to replace Beit Lahia WWTP and serves the whole of the Northern Governorate to a future design of 2025 for an ultimate flow of 60,000 m^3/day (22 MCM/year). The effluent reuse strategy is based on agricultural irrigation and

aquifer recharge of effluent outside the irrigation period. Infiltration basins would be located within the WWTP.

☐ Feasibility study of the reuse of TWW for the Gaza Agglomeration (1999).

A study was completed by OTUI in 1999 for the design of a WWTP serving Gaza City and the Middle Area, with a design capacity for 2025 of 170,000 m^3/day (62 MCM/year) to be constructed in four phases. The location of the site was close to the Green Line, immediately south of Wadi Gaza. The effluent standards proposed were BOD 10 mg/l, TSS (5-10) mg/l, total N 10 mg/l, and fecal Coliforms < 1,000 MPN/100 ml. Treatment would be provided by oxidation ditch, sand filtration and Ultraviolet disinfection. The sludge would be dewatered by a belt filter to 18% dry solids, producing 120 ton/day.

☐ Sludge and effluent reuse study for Gaza Central area, concept report (July, 2015).

The study aimed at developing a practicable concept for the utilization of treated effluent and sludge that is expected to be produced by the Central Gaza WWTP. Long-term strategies were identified and developed to minimize negative environmental impacts and to maximize the value of these products. The concepts allowed safe and economically responsible reuse for both agricultural and aquifer recharge purposes. The unanimous conclusion of the study carried out by the KFW putted a high degree of effluent reuse must be performed in Gaza in order to reduce the existing levels of groundwater withdrawal by the agricultural sector. However, agricultural demand is seasonal and aquifer recharge of surplus effluent is widely regarded as the best option to enhance groundwater levels. As effluent will have a better quality than most of the groundwater in Gaza, this will also provide progressive rehabilitation of the existing high salinity concentrations, but this will not necessarily reduce nitrate concentrations. The regional approach to wastewater treatment and location of WWTPs on the eastern border of Gaza assists in maximizing the potential benefits of reuse and recharge. The WWTPs are located far from the population centers and within the main agricultural area of Gaza, thus making effluent distribution to farmers more feasible. Also, groundwater movement is east to west, so recharge effluent will potentially improve levels and quality across much of the GS.

Upgrading works for Al Mawasi wastewater treatment plant.

This study supported by CMWU and was carried out by an individual consultant (Dr. Fahid Rabah). The main objectives of this report were: analysis of the existing treatment process in the WWTP and figure out deficiencies in its physical and/or technical status, and proposing rehabilitation works to upgrade the treatment plant to cope with the expected increase of hydraulic loads to 12,000 m^3/day in the coming 5 years and to modify the effluent quality. The Khanyounis Temporary WWTP was built in Al Mawasi area by ICRC and CMWU between 2007 and 2009. The project was designed as an emergency response to the overflow of sewage from El Amal basin into areas of the city. The TWWTP has a total area of 97,500 m^2 occupied by 4 treatment ponds that has trapezoidal cross sections. The study concluded that, the first pond will be kept as it is in terms of treatment sequence and process. The main process modifications will take place in the second, third and fourth lagoons.

The second lagoon will be converted from anaerobic pond to completely mixed aerated lagoon by installing six surfaces to achieve complete mixing. The third lagoon will be kept as part mixed aerated lagoon, but the surface aerated capacitors should be increased to achieve the required oxygen requirements. The fourth pond (the sedimentation tank) will be divided into two equal sedimentation tanks to improve the sedimentation capacity and increase the efficiency of fecal Coliforms removal.

 Detailed design for the construction of Khanyounis WWTP in GS (UNDP/PAPP, 2010).

This study supported by Japan and was completed by a joint venture consortium between SOGREAH Consultants from France and UNIVERSAL Group for Engineering and Consulting (UG). The project was divided in 6 duties: topographical survey and geotechnical analysis, initial design report,, preparation of completed detailed design for Khanyounis WWTP, preparation of the client's requirements and preparation of tender documents for Khanyounis WWTP Phase I, carrying out environmental impact assessment studies. According to a recent review of the project design by UNDP (2014), the design figures of Khanyounis WWTP, Phase I, are based on a flow of 26,600 m^3/day to serve 217,000 residents and load

estimates for the year 2018, while the design figures of Phase II are based on a flow of 44,900 m^3/day to serve 376,000 residents and load estimates for the year 2025. The overall project of Khanyounis WWTP, Phase I, was split into the following four complementary construction components:

- Construction of Khanyounis WWTP and buildings, including carrying out one year of operation after commissioning of Khanyounis WWTP.
- Construction of main pressure lines to the sea and to the infiltration basins.
- Construction of the infiltration basins in Al-Fukhari area.
- Construction of electrical power supply to the WWTP.

☐ **Attaallah (2013)** conducted a study to investigate the short-term effect of irrigation with reclaimed wastewater from Gaza WWTP Plant on physiochemical properties of soil, groundwater and fruits. The results show that significant difference in EC, TDS, NO3, Cl-, Mg+2, Ca+2, Na+ and OM were reported, particularly at top soil layer (0-30 cm) more than (30-60 cm) layer. Results also showed no microbial contamination in the olive and citrus fruits. Additionally, the levels of the heavy metals were reported to be low. Olive oil quality parameters indicated no significant variation in refractive index, free acidity, peroxide value and acid value extracted from olive fruits from both plots.

☐ **Nassar et al. (2010)** discussed the most feasible option of proposed three main disposal: use in irrigation, aquifer recharge and disposal to Wadi Gaza. The results show that the predicted effluent quality is suitable for irrigation of a wide range of crops, with only marginal reduction in potential yield provided that the irrigation with leaching regime is appropriate to control soil salinity. The most appropriate effluent reuse strategy should be dependent upon a direct supply for crop irrigation and the surplus recharged to the aquifer.

☐ **Abu Nada (2009**) has studied the effects of TWW irrigation on soil and crops, properties at Om Al-Naser village into the north of Beit Lahia Pilot Project, where wastewater effluent was used for alfalfa irrigation and the analysis were done for soil, wastewater, and alfalfa plants.

Results revealed that Beit Lahia WWTP effluent is suitable to be used for irrigation as its quality matches the local and international standards for wastewater irrigation except Na, Cl and Pb. Long term wastewater irrigation increased salt, organic matter

and plant nutrients in both soil layers, but soil PH was not regularly affected. Pb was the dominant heavy metal in wastewater and alfalfa crop. Although Pb level was in the acceptable range of soil, it was noticed that Pb has higher levels in alfalfa compared with other metals. Alfalfa yield irrigated with wastewater was higher than alfalfa yield irrigated with fresh water in the first year. The study concluded that regular monitoring of site-specific water and soil and appropriate management are needed to mitigate the negative impacts of sodium and salt accumulations.

☐ **Nassar et al. (2009)** has investigated the socio-economical aspects of reuse in the GS. The study was conducted by using field investigations and questionnaire analysis. The field investigations are concerned about the potential lands for reuse and models to identify the quality of irrigated water in two agricultural areas in the GS. In Biet Hanoun (North Gaza), 68% of the farmers agreed to use the TWW for irrigation purposes, In the Southern area, 91% of farmers accepted direct wastewater reuse schemes. The educational level, standard living, and the environment played a remarkable role in convincing the farmers about the feasibility of using TWW. The study indicated an economic improvement for farmers switching from groundwater for effluent irrigation.

☐ **Othman (2004)** has studied the using of treated gray water for irrigation of rain-fed olives. The study is concerned on the effect of different water regimes with different quality on the growth and production of "Nabali" olive cultivars. Thirty years old olive "Nabali" trees were irrigated from April 2000 to July 2002 with both types of water (fresh and wastewater) and three levels of water (20,25,30 m^3/tree/year). Each level was applied for a tree. Irrigation was applied by drip laterals. The experiment was conducted in the Beit Doko village, close to Jerusalem in the West Bank (WB). Both types of water significantly increased olive yield compared to that obtained in the control. A higher vegetative growth (shoot number and length) was obtained with a higher water level (30 m^3/tree). The results of this study indicated that this kind of TWW is suitable for irrigation of olive orchards.

☐ **Afifi and Tubail (1998)** has studied the effects of TWW reuse in agriculture on soil and plants. The study conducted in a greenhouse of 1000 m^2 near BLWWTP in the northern GS. The greenhouse was divided into three parts which irrigated with

three different types of water (100%, 50%, 0 % TWW) and three different crops were used in the study (eggplant, tomato, and pepper).

The results showed a positive effect of using TWW as fertilizer for the main three nutrient elements (N, P and K). Also, fecal Coliform (FC) and parasite in the eatable parts of different crops, increased with increasing the percentage of TWW. The soil samples analysis before and after the study indicated limited changes in soil chemistry, however, the biological contamination of fecal coliform in top soil level was higher than in deeper soil level and increased with increasing the percentage of TWW.

☐ **Nazer et al. (2010)** had built an optimization model to the irrigation water allocation in the West Bank (WB). The Solver function enabled by Microsoft Excel is used to build the linear model because it is simple to use and easy to manipulate for end users. Five agricultural zones and five fruit and vegetable crops under three scenarios were considered. The main goal was to maximize the profit under the constraints of land and water availability as well as local consumption of the crops. It was found that changing the cropping pattern may reduce water used for irrigation by 10%. It was also found that water scarcity problem can be well coped with if rain-fed agriculture replaces irrigated agriculture.

In addition, there were many attempts and studies to reuse wastewater in the world, a few of them are summarized as follows:

☐ **Hamdy and Liuzzi (2005)** conducted a research to suggest a tool to overcome water scarcity and quality constraints in the Mediterranean region by developing an appropriate water pricing system, aimed at promoting efficiency and sustainability of water management as well as the cost of water services offers high potentiality.

☐ **Jaradat (2010)** evaluated the existing water demand and supply conditions and expected future demand and supply scenarios taking into account the different operating policies and factors that affect demand. Three scenarios are (1) Current State (2) when the economy moves on but no development in the political conditions. (3) An independent state with economy moves on. And the results show that the water demand will vary according to three scenarios; the water demand will increase from 201 MCM in scenario 1, to 266 MCM in scenario 2 to 371 MCM in scenario 3 by the year 2020. And the water demand gap will be filled if scenario 3 achieved; it

turns out to be zero until year 2018. Even that the gap will be 74 MCM in scenario 2, and 105 MCM in scenario 1.

□ **Sanjaq (2009)** attempted to develop an integrated water resources management for the area which is served by Jerusalem Water Undertaking (JWU), by using (WEAP) model. WEAP model allows analysis and simulation of various water allocations, the concept of regional utilities and its impact on water management was evaluated. Three management options for JWU are investigated. The three options which were developed into WEAP and tested as follows: Option 1: pumping water from Eastern Aquifer Basin Option 2: pumping water from Western Aquifer Basin Option 3: pumping water from Both Aquifer Basins. The results obtained in this study show that the service area of the central water utility should be connected together to allow better management of the available water resources.

□ **Agrafioti et al. (2012)** concluded that the agricultural irrigation with TWW could be implemented on the island of Crete. Analysis of effluent qualitative data indicated count 13 from total 15 wastewater treatment plants throughout Crete meets the proposed criteria for olive tree and vineyard irrigation without any additional treatment. However, vegetable irrigation requires further advanced tertiary treatment. Estimation and visualization of the irrigated land showed that wastewater can be used as an alternative water resource to irrigate a significant agricultural area. Consequently, wastewater reclamation and reuse can reserve great amounts of fresh water, which can be used in order seasonal water shortage to be confronted.

□ **Elamin and Saeed (2008)** has evaluated the impact of using TWW for irrigation under Khartoum State conditions. The experimental treatments TWW alternating with River Nile water and River Nile water in combination with three different tillage operations: harrowing, disc ploughing, and chisel ploughing. Replicated samples taken from soil depths (0-20), (20-40) and (40-60) cm. "Abu Sabein", a variety of forage sorghum (Sorghum bicolor), was used as an indicator plant. Chemical analysis showed that the level of different constituents of TWW conforms to the Food and Agriculture Organization (FAO) standards for irrigation water. TWW significantly increased PH, EC, Pb, DOC, N, K, Cl, Cu, Fe, Zn, Mn, Na, Ca, Mg, P and Co in the soil, followed by irrigation with TWW alternating with River Nile water and irrigation with River Nile water. Similarly, highly significant effects

were also recorded for plant growth parameters and forage yield. Tillage operations and depths showed significant effects on the distribution and concentration of trace elements and nutrients in the soil. High transfer factor was registered for Ca and Co, followed by P, K, Cu, Zn, Pb, Fe, Mn and Na.

☐ **Shahalam et al. (1998)** has studied the impact of wastewater irrigation on the soil, percolating water, crop growth, and the pathogenic condition within the immediate vicinity of wastewater application. The experiment was carried out at the Agricultural Research Station at Jordan University of Science and Technology. Experimental plots with three crops: alfalfa, radish and tomato were irrigated with fresh water and wastewater. The irrigated water was applied by sprinklers. Each crop was given two sub-treatments: with fertilizer and without fertilizer. The physical and chemical properties of the soil, the crop yields, and subsurface drainage were measured. In most cases, the yields resulted from the uses of wastewater with fertilizers were compatible with those of the uses of fresh water with fertilizers.

Chapter Three
Study area

Three Chapter
Study area

There are many major environmental problems in Rafah due to long occupation period by the Israelis and siege. Thirty years of deteriorating infrastructure and negligence, over the period (1967-1994), lead to inadequate investment in the various especially environmental sectors linked in water and wastewater.

Overpopulation is also a major challenge that creates more pressure, especially on the limited natural resources in the area and has a profound impact on the quality of health and social life of people. During the period some of the existing infrastructure deteriorates while the population and their needs quickly increased. This leads to environmental deterioration on almost every aspect. The quality of the groundwater is a major problem in Rafah.

3.1 General Description of the Study Area
3.1.1 Location and Population

Gaza Strip (GS) is the south-western part of Palestine, bounded by the Mediterranean in the west with longitudes 34°20", latitudes 31°16", 31°45"N and 34°25"E (Aish et al., 2004). The total area of the GS is 365 km² with approximately 45 km long and 6-12 km wide (El Baba et. al., 2015). GS being considered one from the area of the densest populated areas throughout the world. According to the PCBS records in December 2016 the number of inhabitants of the GS in Mid 2016 is 1,881,135 inhabitants. Rafah governorate is one of the five GS governorates in the southern GS and is located 30 km south of GS, with a current population around 233,490 inhabitants (with roughly 65 % children, 17 % women and 18 % men) live in area 64 km². The built up area is 10.7 % of the total urban area in GS Projected population in 2020 become 264,174 inhabitants and in 2030 will reach 338,321 inhabitants (PCBS, 2016).

3.2 Climate and Precipitation

GS residents are suffering from a sharp decrease in rainfall quantities, it decreased areas a move to Rafah at south reach only 250 mm. The United States Environmental Agency has classified areas into arid areas and non-arid areas based

on rainfall of 312.5 mm/year to be the reference (Al-Qutob, 2016). Because Rafah is existing in the transitional zone between the Sinai Peninsula desert climate and the semi humid Mediterranean climate. (Shomar, 2006). For these reasons Rafah climate is divided into only two main seasons:

☐ Summer dry season that runs from 1st April till 30th September, and

☐ Winter wet season that begins in 1st October and ends in 31st March.

3.2.1 Humidity

The relative humidity of the air is highest near the coast and higher during the evening in summer than in winter. Humidity reaches its daily minimum around noon and a maximum late at night or throughout the night. Generally, for GS, in summer the humidity varies between 65% in the daytime to 85% at night, while in winter it varies between 60% in the daytime to 80% during the evening.

Humidity is derived from evapotranspiration and means daily evaporation varies from 2.1 mm/day in December to 6.3 mm/day in July, the average annual potential evaporation lies between 1,200 – 1,400 mm/year (RABOU, 2017).

3.2.2 Winds

In summer, sea breeze blow all day and land breeze blows at night. The source of prevailing winds in the summer is the northwest. There are clear daily fluctuations in the speed of wind during this period of the year. Wind speed reaches its maximum value at noon period, which is 3.9 m/s and decrease during night. During the winter, most of the wind blows from the southwest with an average speed 4.2 m/s. In summer, strong winds blow regularly at certain hours. Mornings are usually calm in most areas of Gaza Governorates as are nights (EMSS, 2014).

3.2.3 Topography and Soil

Rafah topography is apart similar of GS topography that represent extended ridges and depressions, dry streambeds and shifting sand dunes in coastal areas (Hamada et al., 2011).

The GS has composed primarily three soils shown in Figure (3.1): sand, clay, and loess. The sandy soil exists in coastal areas as shape sand dunes with thickness vacillates from 2 meters to 50 meters, Clay soil exists in northeastern of GS. Loess soil thickness ranges from 25 meters to about 30 meters (Aish, 2010). Rafah has a major both sand and loose soil as shown in Figure (3.1).

The types and the presents of each soil type in Rafah governorate are as follows:

☐ 20% clay (Alluvial Soil).

☐ 60% yellow sand and Mawasi (Loessial Soil).

☐ 20% sand (Loess Soil).
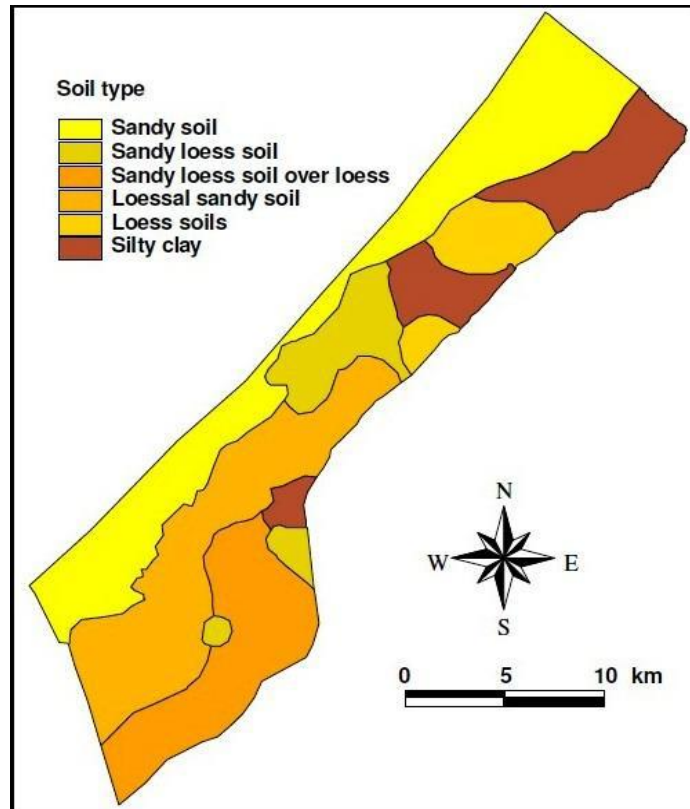
Figure (3.1): Soil map of GS (PWA, 2004)

3.2.4 Sewage System in Rafah

The sewage system consists of three basic components: the collection network, the pumping stations, the treatment plant and the disposal of wastewater. Prior to 1982 Rafah governorate depend on the cesspit tanks with depths of 3-5 meters.

- In 1982 Block O pump station and the Al Sabeel pump station were established, it's considered the first establishment of sewage network, it is a pipe for the discharge of rainwater collected on the Egyptian-Palestinian border in a Block O area, This water considered hinder the movement of Israeli military patrols because was collected in a low area, therefore, the Israeli authorities established the project of the Block O pump station. At the same time in the refugee camps in Rafah, there were drainage open channels from Kitchens and home bathrooms, but the toilets were often connected with

cesspit tank inside the home. The UN funded drainage open channel system in most refugee camps (B, C, E, F, G, H, I, J, K, L, M, N, O, and P), after that the network of drainage open channels was connected to Block O pump station.

- In 1986 constructed pump station of Tal-Sultan and next year constructed main collection plant in sandy area south-west of Tel-Sultan area (which later developed into RWWTP) it has a booster pumping to the sea. At that time, the rainwater was collected in two areas, one of which was the land at the time west of the center of the Kiir area, about 2 dunums, and the second area east of the Tel-Sultan station. The water at that time covered more than 20 dunums, the resulting water was discharged into the main collection plant in sandy areas at south-west of Tel-Sultan.

- In 2001, Jenina Pump Station was established after the network was established in the Eastern Region (Brazil, El Jenin and Hay Salam).

- In 2002, the Al Sabeel pump station was established.

3.2.5 Sewage Pump Stations in Rafah

Table (3.1) shows the pumps operating in the sewage plant in Rafah and the capacity of the pumps, the following is an excerpt about it.

Table (3.1): Information about pumps operating in the sewage system in Rafah

NO.	Name of Pump Station	Number of Pump	Pump Type	Power (KW)	Capacity (m^3/h)
1	Jenina (booster1)	3	Submersible	54	250
	Jenina (booster 2)	3	Submersible	54	250
2	Al Sabeel	3	Submersible	90	500
		1	Mobile	105	750
3	Tal-Sultan	2	Submersible	110	440
		1	Mobile	25	590
4	Block O	2	Submersible	4.4	75
5	UNDP	2	Submersible	7.5	50

3.2.5.1 Jenina Pump Station

The pump station was constructed in the year 2000 after the need for sanitation service in the eastern areas of Rafah, Hay Salam, Jenina, Khirbet El-Adas, and parts of the Hay Edary areas. The station was founded by SCF in addition constructed main and branch networks to Jenina pump station, achieved works by Contemporary Company for Contracting.

3.2.5.2 Al Sabeel Pump Station

The station was established in the year 2002 to serve the low-areas of the western region of Rafah and it consider the main station is in Rafah, where it receives at least 70% of the sewage in Rafah. The station was established with funding from the World Bank, the Palestinian Water Authority, and Rafah Municipality, achieved works by Contemporary Company for Contracting.

3.2.5.3 Tal-Sultan Pump Station

The Tal-Sultan pumping station is one of the oldest stations in Rafah. It was established in the past to serve populations in Tal-Sultan area only, and due to the expansion of the surrounding area of Tal-Sultan, the pump station was rehabilitated in 2010 by the UNRWA, achieved works by Abu Warda Company for Contracting.

3.2.5.4 Block O Pump Station

The old station was during the Israeli occupation near the Egyptian-Palestinian border and the entire station was destroyed during the Israeli invasion of the border areas. The site was relocated and reconstructed in the year 2003 in partnership with SCF. Where all the electromechanical and construction facility was targeted. After the withdrawal of the Israeli occupation in 2005, the station was fully completed maintained in the year 2006.

3.2.5.5 UNDP Pump Station

The station was established in the year 2013 to serve the government housing project donation with funding from the United Nations Development Program (UNDP), Located in Freedoms area (common name after Israeli withdrawal) at west Tal-Sultan, achieved works by Amer Sons Company for Contracting. Figure (3.2) shows the current and future pumping station and the direction of flow.
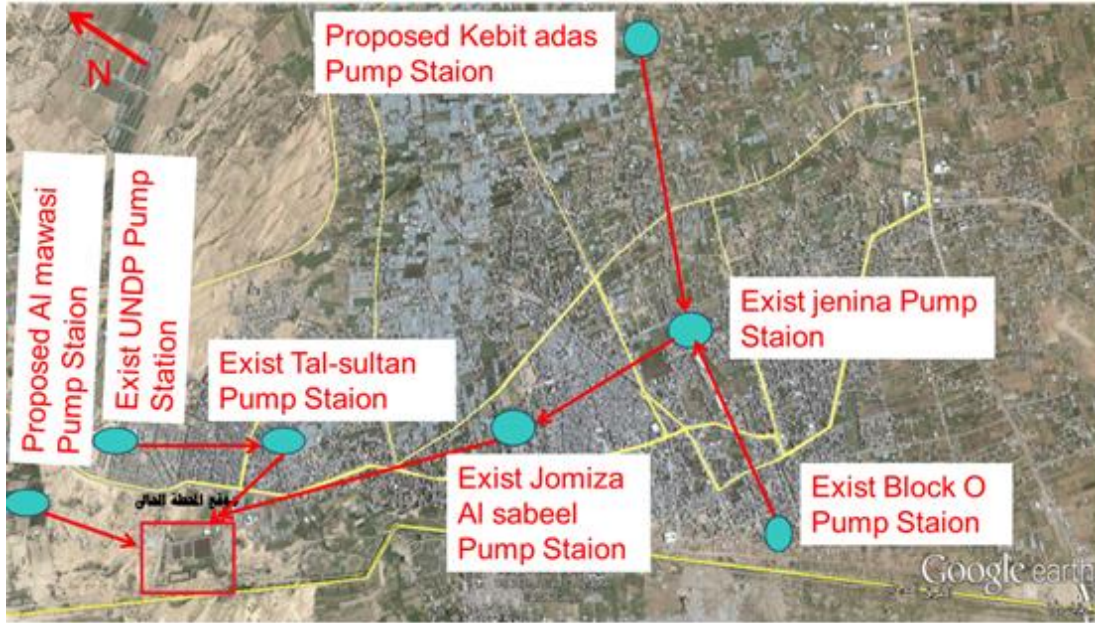
Figure (3.2): Current and future proposed pump stations in Rafah governorate

3.2.6 Flow Rate Projection

3.2.6.1 Water Demand for Rafah Governorate and the Refugee Camp

From the previous consumption statistics (according to the Water and wastewater department in Rafah) it is clear that:

- Average per capita consumption in the refugee camps of 60-80 liters/person/day.

- Consumption per capita in the city is about 110 liters/person/day.

Table (3.2) shows the quantity of water produced from municipal wells, UNRWA wells and private desalination plants equal to 999,715 m^3 / year for Population 233,490 inhabitants.

$$\text{Avilable water (L/C/D)} = \left(\frac{\text{Production } (\text{m}^3 / \text{year}) \times 1000}{\textit{Population} \quad \text{Number} \times 365} \right) = \frac{9{,}995{,}715 \times 1000}{233490 \times 365} \approx 120 \ \text{L/C/D}$$

In the previous step meet with prediction of water consumption, according to PWA strategy the water consumption for the years 2016 is 120 L/C/D.

Table (3.2): Domestic water production in Rafah governorate and Population
(BCPS, 2016; and PWA, 2016)

Area Name	Population (capita)	Municipality wells Production m³/year	UNRWA Wells Production m³/year	Private Desalination Plants (m³/year)	Total Water Supplied m³/year
Al Naser	8,367	419,395	-		
Al Shouka	14,236	501,186	-	717,590	9,995,715
Rafah city	210,887	8,181,144	176,400		

3.2.6.2 Sewage Flow Rate

The sewage flow rate is established by considering the source, corresponding water usage rates and the type and condition of the sewer. The expected variations in the sewage flow rate must be established before the sewers and treatment facilities are designed, the wastewater production can be calculated for the same years.

Number of Rafah residents = 233,490 capita (BCPS, 2016).

Per capita consumption in the GS 120 liters / day = 0.12 m³/day.

Wastewater Production (m³/day) = wastewater consumption per Capita * population * 0.8 = 22,415 m³/day. Thus, it is worth to consider treating effluent as a resource of water for irrigation purposes.

3.3 Rafah Wastewater Treatment Plant (RWWTP)

RWWTP is one of main treatment plants in the GS, these exist to prevent any further environmental degradation and eliminate hazards to public health, the CMWU through the Project Management Unit proposed a project to upgrade the treatment plant with an implementation plan of three phases. The proposed project has been submitted to the International Committee of Red Cross (ICRC) on April 2008. The CMWU had completed the 4 phases of rehabilitation and upgrading of RWWTP through the proposed project Rafah emergency sewage treatment Plant Project as shown in Figure (3.3). The CMWU is responsible for the operation and maintenance of the water and wastewater services in GS. Among its responsibilities, the operation and development of current WWTP is a top priority, with the main goal to provide an environmentally sound solution to solve the overloading problem, which currently receives average 12,000 m³/d, and current maximum capacity of the treatment plant reaches 20,000 m³/day, International Committee of the Red Cross

supported technically and financially the CMWU for the last development phase of the RWWTP.

Figure (3.3): Aerial image for RWWTP site

3.3.1 Location

RWWTP is located in the western part of the Rafah governorate at Tal-Sultan area around 500 m nearby the borderline with Egypt. The site is surrounded by sand dunes, The RWWTP project site area is about 13.35 hectares with sandy road access from northern direction, the average topographical level is about 27 m above MSL, and the project area is about 2 km from sea beach (ICRC, 2009).

3.3.2 The Stages of Development of the Treatment Plant since its Construction

The description demonstrates the situation before the emergency intervention of the CMWU/ICRC take place in the year 2008. The RWWTP was established in 1987 (funded by saving the children federation), where a collection lagoon without treatment with the capacity of the plant was is 4,000 m^3/day.

As shown schematic Figure (3.4), in 1992 plant improvement and installation the electromechanical equipments to limit the negative environment impacts and protect human health from the lagoon. According to Obaid, 2014 these elements are:

3.3.2.1 Micro Rotostrainer

The microstrainer installed at the inlet of the treatment plant in order to sieve the inlet wastewater from debris with a size of more than 0.5 mm, so it was working similar to the primary settling tank - to reduce the BOD - by removing the screening organic matter.

3.3.2.2 Surface Aerators

Four 7.5 KW surface aerators were installed to supply the Biomass with oxygen for aerobic process.

3.3.2.3 Aero Mixtures (spiral aerators)

Two 10 KW spiral aerators were installed at the two corners of the lagoon for aerobic process, also to eliminate the water stagnation at the corners.

3.3.2.4 Chlorination Unit

For disinfection the effluent through the chlorine contacting chamber.

3.3.2.5 Effluent Pumping Station

Two 40HP vertical turbine pumps were installed for discharging the effluent treated water to sea.

3.3.2.6 Discharge Pressure Line

Pipe 250 mm (10") diameter and 3000 m length were installed to transport the effluent treated water to the sea.

3.3.2.7 Standby Generator

230 KW power supply generator was installed to supply the treatment plant with required power needed.
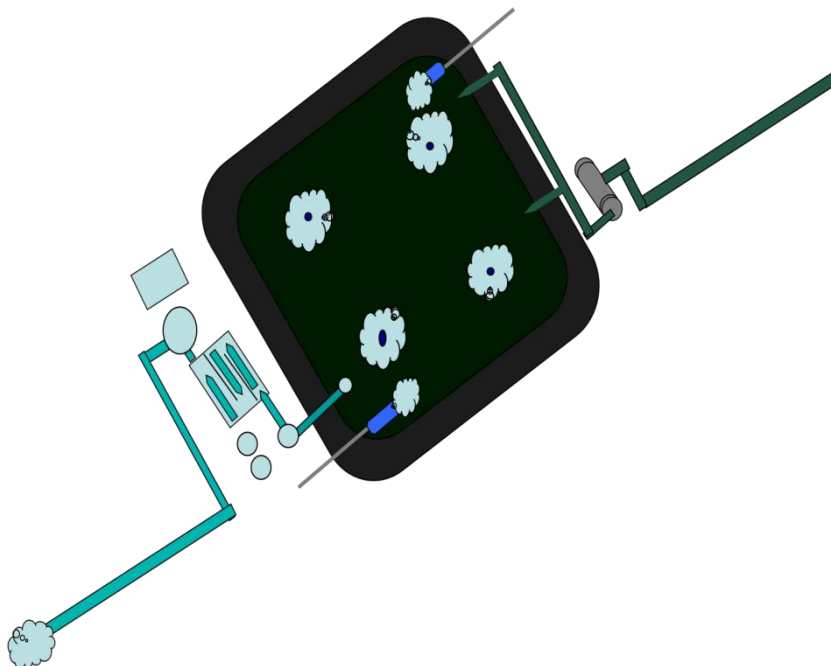
Figure (3.4): Old RWWTP schematic diagram (obaid, 2014)

A little of change has taken place in 1998 by adding two elements, construction a grit removal, installation submersible pumps.

Great improvement was in 2008 and after, the need to make GS public beach clean, and to save the health visitors, one of the essential things has to be done for that, Coastal Municipalities Water Utility (CMWU) has to improve the quality of the treated wastewater in GS (especially at Rafah and Gaza treatment plants).

In the siege imposed on Gaza International Committee of Red Cross (ICRC) allocating the fund for upgrading RWWTP. Due the lack of construction materials, the construction materials of the treatment plant was the reused materials (separation wall concrete segment and crush concrete). Table (3.3) summarizes different phases of development from 2008 until now.

Table (3.3): Different phases of RWWTP development

Phase NO.	Project Description	Project Cost USD	Project Start	Project Finish	Donor
Phase 1	Construction of two anaerobic lagoons	700,000	25/07/2008	15/06/2009	ICRC
Phase 2-A	Construction of Bio-towers(Phase2, part1)	1,350,000	09/11/2009	18/10/2010	ICRC
Phase 2-B	Construction of administration building and pump station. (Phase 2, stage B)	586,000	09/11/2009	18/10/2010	ICRC
Phase 3	Construction of carrier force main pipeline.	247,000	May,2010	08/08/2010	ICRC
Phase 4	Development of RWWTP (Planting, agriculture works and furniture).	246,000	20/04/2011	25/08/2011	ICRC
Total:		**3,129,000**			

Every stage have activities, first stage includes inlet energy breaker for inflow, construction of new grit removal "concrete channel", construction of two new anaerobic lagoons, each of 8,000 m^2 area, construction of drying beds and

construction of 14 "force main from effluent pump station to the Sea. Second stage includes: Part "A" two bio-towers, piping, polishing pond and distribution chamber (the main scope of this contract), Part "B": effluent pump station and part "C": sea outfall. Third stage includes Infiltration ponds, wetland, and sludge handling pond.

Fourth stage includes agriculture of reeds in reed beds and around the basins to increase processing treatment efficiency and Cultivation of spaces in the grass to give the aesthetic appearance of the plant.

3.3.3 The Stages of Current RWWTP

The process of the current RWWTP shown in Figure (3.5) as the following:

3.3.3.1 Inlet Structure

Pre-treatment element include grit removal channel constructed from concrete, Length equal 12.5m and volume admitted equal $25m^3$, at the front of the channel which functions as an energy breaker. Table (3.4) shows the Rafah WWTP is supplied by two pumping stations: Tal-Sultan pump station and Al Sabeel pump station.

The first station is El Jumaza pump station, which is receives the wastewater from the western area of the city and received by earth gravity from El Junina pump station, which received the wastewater from the collection system of the eastern area of Rafah city (Salah Edin st., khrbet EL Adas and block O). The second pump station located at Tal-Sultan and it pumped the wastewater collected at this suburb and from the UNDP pump station.

Table (3.4): Flow rate and head for pump stations supplies to RWWTP

Description	Tal al Sultan Station	Al Sabeel Station
* Number of pumps	3	2
* Pump details [each pump]	250 m³/h at 40m	512 m³/h at 40m

3.3.3.2 Venturi Channel

After the grit removal channel, a Venturi channel it is equipped flow rate measurement for inflows.

3.3.3.3 Primary Anaerobic Ponds

Two anaerobic lagoons to provide a biological treatment of wastewater under conditions of oxygen deficiency, each lagoon is 5m depth and trapezoidal shape of rectangular bottom base of 77 m length 4 m width and the upper base of 110m length 80m length and total volume 30,000 m^3.

3.3.3.4 Settling Pond

One aerated lagoon with depth of 2.7 m and trapezoidal shape. The square bottom base dimension is 110 m length 110m width and the upper base of 130 m length * 130 m width and total volume 40,000 m^3 with four aerators provide Oxygen for treatment of wastewater. The settling ponds are an old structure, originally designed as an anaerobic pond, it was afterwards converted in an aerated lagoon and with the latest works, it has been planned to be used as a classifier for the waters issued by the bio-towers and allow for suspended solids to settle.

3.3.3.5 Distribution Chamber

Its pumps receive the water from the anaerobic ponds and directs the wastewater to the Bio-towers. The chamber is currently equipped with 3 pumps (each 350 m^3/h at 12 m head), 2 pumps can work together, 1 is on stand-by, an extra space is already planned for a 4th pump.

3.3.3.6 Reed Beds (wetland)

According to the process described in the Term of References, the function of this wetland is to reduce nitrogen (TKN) and residual suspended solids from the effluent.

3.3.3.7 Infiltration Pond

Two infiltration basins are constructed to receive the effluent of the constructed wetlands. The surface area of each basin is 10,500 m^2 and a volume of 30,000 m^3. According to the ICRC's conceptual design, it is proposed to dig recovery wells after the construction of the infiltration basins as a method of indirect reuse of the treated effluent.

3.3.3.8 Sludge Drying Bed

200m length, 1m high and 15m width divided into two concrete slabs 7m each separated by 1m aggregate bed. The main function of the beds is to dry and decrease the volume of the sludge and treat before disposal.

3.3.3.9 Electrical Installations

The Rafah WWTP is equipped with a 600 KVA transformer installed on the main power grid, another there exist two generators in partial operation a (400 KVA) generator and a second generator (110 KVA).

3.3.3.10 Effluent Pumping Station

The outlet pump station is designed on the same model as the distribution chamber: a chamber collects the effluents from the settling pond which deliver treated wastewater to the sea. Four pumps (3 in operation + 1 standby) with a total capacity of 1,050 m³/h.

Currently, all treated water goes to the sea, but the design indicates the dumping of effluent into the sea will occur only in two cases. The first case is when the infiltration basins are overloaded for any reason and the second case when the treated effluent quality is not meeting the infiltration standard for any reason, such as the case of maintenance of the treatment units or when one or more units are malfunctioning.
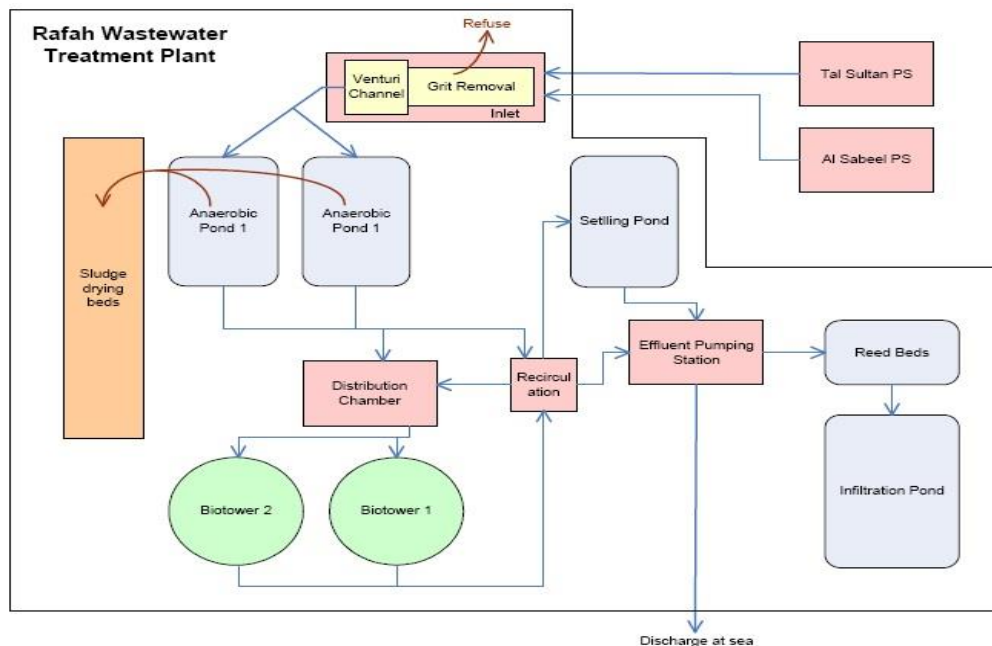
Figure (3.5): The existing Rafah WWTP Processing scheme (ICRC, 2013)

3.3.4 Future Planning of RWWTP

The future development as shown in Figure (3.6) planned to add a third trickling filter/biotower is reaching more than current limits.
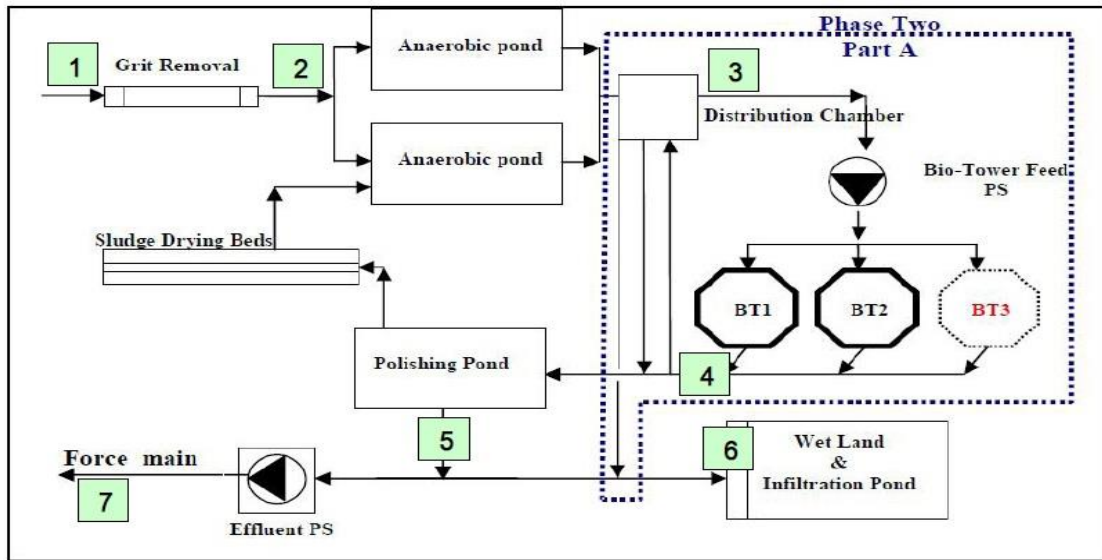
Figure (3.6): RWWTP Schematic diagram

3.3.5 Influent Variation of RWWTP

Figure (3.7) shows the variation of the inflow to the treatment plant from January 2015 to December 2015, the received wastewater by RWWTP is varied from minimum flow of 10,662 m^3/day in March to maximum flow around 14,000 m^3/day in December and January.

Months (October, November, December, January) is winter, the water coming to the RWWTP increases due to stormwater, and decrees in summer months (June, July, August).
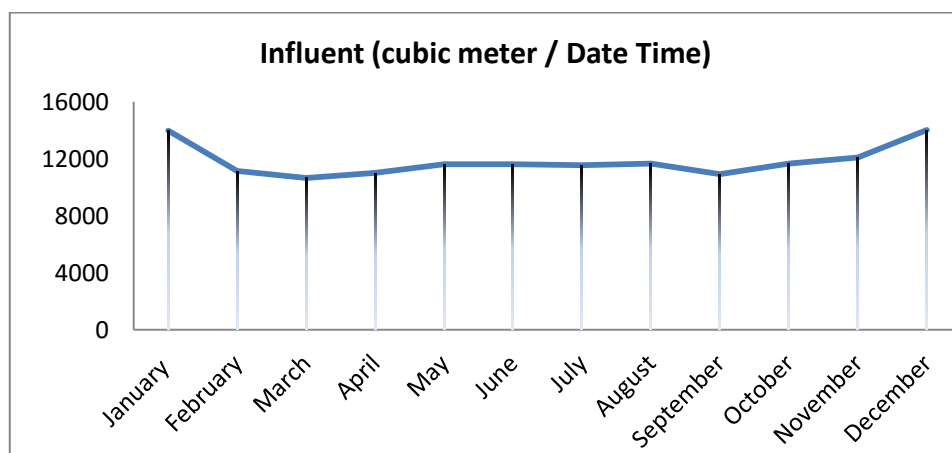
Figure (3.7): Variation flow Vs. Time (m^3/d)

3.4 Agriculture Land and Crops Types

Agriculture has been a long time and vital part of the Palestinian economy, both in the WB and the GS, in terms of the number employs in this sector and contribution in gross domestic product (GDP) of Palestine. Which contributes to 32% of its economic production. Throughout the most recent 5 years, its contribution to the GDP has decreased from 9.10% in the year 2000 to around 7.00% in year 2005 (Al-Najar, 2007). While it increases during the year 2013 to achieve 12.2% of gross domestic product, which means that the period of the study is located in economic growth due to the farmer have been imported seeds, fertilizers and pesticides from Egypt illegally (MOA, 2013).

The agricultural sector in GS has various crops, the primary permanent trees are olives, almonds, date palm, apple, grapes, apricot and citrus. In addition to wide range of vegetables such as potato, eggplants, pepper and tomato. Rain-fed crops such as barley and winter wheat cultivated in winter season only. Table (3.5) illustrates crop categories and Table (3.6) shows the cultivated area and the volume of production of each type of crop in Rafah Governorate.

Table (3.5): Crop categories

Crop Category	Crop Type
Citrus Orchards	orange - lemon - graperfruit
Vegetables 1	cucumber - cabbage
Vegetables 2	tomato - sweet peppers - egg plants - potato
Mixed Agriculture	date palms - grapes - guava - strawberries
Tree Orchards	olives - almonds - apples - pears - peaches - apricots
Field Crops	winter wheat - barely

Tabel (3.6): Information about crop type, cultivated area and production in the Rafah governorate (MOA and MOR, 2018)

Crop	Production (ton)	Area (dunum)	Area Percentage %	المحصول
Olive	327	2960	30.03	زيتون
Almond(Hard)	165	1100	11.16	لوز يابس
Valencia Orange	1962	654	6.64	برتقال فلنسيا
Date	285	475	4.82	بلح

Crop	Production (ton)	Area (dunum)	Area Percentage %	المحصول
Aloe	320	320	3.25	صبر
Guava	690	280	2.84	جوافة
Lemon	324	247	2.51	ليمون
Poppy	264	215	2.18	خلال
Peach	125	188	1.91	خوخ (دراق)
Grape	318	175	1.78	عنب
Apple	8	75	0.76	تفاح
Fig	26	37	0.38	تين
Apricot	6	27	0.27	المشمش
Grapefruit	60	25	0.25	جريبفروت
Others	95	38	0.39	أخرى
Other Citrus	38	19	0.19	حمضيات أخرى
*Agricultural land not cultivated		3021	30.65	أراضي زراعية غير مصنفة
Total	5013	9856	100.00	المجموع

* Agricultural land not cultivated: according to the master plan of Rafah is classified as agricultural land but mostly blank.

Chapter Four

Methodology

Chapter Four

Methodology

This chapter highlighted an outline of research methods that were followed in the study, aim to provide information for inclusion in the study, therefore the methodology of the study dived into two parts, first part collection and analysis of wastewater samples taken from RWWTP, and the second part distribute a questionnaire to farmers then statistical analysis.

4.1 Part I: Quality Measurment

The samples were taken from outlet of RWWTP, due to the importance of the wastewater properties on agricultural practices, it is necessary to determine its characteristics before consumption. Its chemical and biological properties need to be properly conserved. Where wastewater analyzed according to the American Public Health Agency (APHA, 2005). The sample collection before winter seasons in a sunny day on Tuesday 10/10/2017.

4.1.1 Method Used for Sample Collected

A composite sample device was used to take samples from RWWTP effluent, this device programmed to take 200 milliliters per hour during a 24hr period is considered standard for most determinations.

The Samples was collected from RWWTP effluent in a clean plastic bottle 2-liter after mixed sample collected by sampler device and put in ice box, also collected samples for microbiological, chemical, and heavy metals analysis in sterile bottle and then sent to the Islamic university laboratory. Wastewater analyzed according to the American Public Health Agency (APHA, 2005).

4.1.2 Tested Parameters

The laboratory conducts physical, chemical, biological, and heavy metals on the effluent quality of wastewater by RWWTP, which may affect the use of wastewater for agricultural irrigation, the following parameters were performed: BOD_5, COD, NH_4, TKN, NO_3, P, Cl, TSS, FC, TDS, PH, EC, Cd, Pb, Cu, Na, Ca and Mg. Then calculated sodium adsorption ratio (SAR).

4.1.2.1 Hydrogen Potential (pH Value)

Field pen pH meter (HI-8424) was used for measuring the pH value. The pH meter probe was washed with distilled water and dried prior to immersing the electrode in the sample and the readings were recorded.

4.1.2.2 Electrical Conductivity (EC Value)

Measuring conductivity was done by using auto ranging EC meter (TH-2400), that measuring the resistance occurring in an area of the test solution defined by the probe''s physical design in (µs/cm) values in microsiemens/cm.

4.1.2.3 Soluble Sodium (Na^+)

Flame photometer Figure was used to determine Soluble Sodium.

4.1.2.4 Soluble Calcium (Ca^{++}) and Magnesium (Mg^{++})

Soluble calcium and Soluble Magnesium were determined using EDTA Titration method**.**

4.1.2.5 Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio was estimated by calculation after determination of Ca, Mg and Na concentrations in the wastewater. Sodium was determined by flame photometer, calcium was determined titrimetrically using (EDTA method) and Magnesium was estimated as the difference between hardness and calcium as CaCO3. The water-soluble Ca^{++}, Mg^{++}, and Na^+ was used to determine the SAR by dividing the molar monovalent cation Na+ by the square root of the molar concentration of the divalent cations Ca^{++} and Mg^{++} (USDA, 2004).

4.1.2.6 Nitrate NO3-

As mentioned in El–Nahhal et al. (2014), NO_3 concentration in wastewater was determined according to salicylic acid method. In this method 5 g salicylic acid dissolved in 100 milliliters H_2SO4. Then 2 milliliters of the solution was transformed to test tubes contained the 1 milliliters of standard solution concentration.

The system is left for 20 minutes. to allow the reaction. The 18 milliliters of $NaOH_6N$ is added to the tubes. A yellow color of salicylic acid is developed. The color in the standard solutions and a known samples were measured at 420 nm. The linear relationship between the optical description and concentration was used to determine the NO_3 concentration in the unknown samples.

4.1.2.7 Total Kjeldahl Nitrogen (TKN)

The total Kjeldahl nitrogen method is based on the wet oxidation of nitrogen using sulfuric acid and digestion catalyst. In the presence of H_2SO_4, potassium sulfate (K_2SO_4), and copper Sulfate ($CuSO_4$) - catalyst, organic nitrogen and ammonia were converted to ammonium. After addition of base, organic nitrogen and ammonium were converted to ammonia, which is distilled from alkaline medium and absorbed by boric acid. The ammonium was finally determined by titration against standard hydrochloric acid (Wang et al., 2016).

4.1.2.8 Total Suspended Solid (TSS)

TSS measured by filtration and drying technique. The sample was filtrated using micro filter. The solids caught by the filter dried at drying oven on 105 ^{o}C and weighted.

4.1.2.9 Ammonium (NH_4)

The distillation technique using distillation unit applied for Ammonium determination. 10 milliliters sample place into micro Kjeldahl tube, then 50 milliliters NaOH solution add to sample, moreover 10 milliliters boric acid added into collecting flask for Ammonium. Finally, a titration step by using 0.1 N HCl use for determination of Ammonium (APHA, 2005).

4.1.2.10 Phosphorus (P)

Phosphorus was measured using the sulphuric acid digestion method, which can determine the concentrations of orthophosphate in most waters and wastewater in the range from 2-200 mg P/L.

4.1.2.11 Chloride (Cl)

The amount of chloride present in wastewater was determined by titrating the given water sample with silver nitrate solution. The silver nitrate reacts with chloride ion, according to 1 mole of AgNO3 reacts with 1 mole of chloride. The titrant concentration is generally 0.02 Mole. Silver chloride is precipitated quantitatively, before red, silver chromate is formed. The end of titration is indicated by the formation of red, silver chromate from excess Silver nitrate (Shan et al., 2018).

4.1.2.12 Biochemical Oxygen Demand (BOD$_5$)

The most widely used parameter of organic pollution applied to wastewater is the 5-day BOD (BOD$_5$). BOD was measured using OxiTop System; the BOD$_5$ is usually exerted by dissolved and colloidal organic matter and imposes a load on the biological units of the treatment plant.

4.1.2.13 Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant.

4.1.2.14 Fecal Coliform (FC)

For testing of FC bacterial populations, The Membrane Filtration technique is performed. In the initial step, several dilutions of the sample volume are passed through a membrane filter with a pore size small enough (0.45 microns) to retain the bacteria present. The filter is placed on an absorbent pad (in a petri dish) saturated with a culture medium that is selective for coliform growth (mFC). The petri dish containing the filter and pad is incubated, upside down, for 24 hours at the appropriate temperature ($44.5 \pm 0.2\ ^{o}C$). After incubation, the colonies that have blue color are identified and counted using a low-power microscope (APHA, 2005).

4.1.2.15 Heavy Metal (HM)

Heavy Metals are tested based on the operating procedure for the Atomic Absorption Spectrophotometer using the appropriate lamp for each element. The (DTPA) reagent should be of the acid form. The theoretical basis for the (DTPA) extraction is the equilibrium of the metals in the sample with the chelating agent (Abu Nada, 2009). The most efficient and main sources well suited for determination of Pb, Cd, and Cu.

4.2 Part II: The Questionnaire

A research design is the overall plan for obtaining answers to the questions being studied and for handling some of the difficulties encountered during the research process (Polit and Beck, 1991; 1998; 2001). The objectives of the questionnaire is to investigate the farmers knowledge of wastewater treatment, their willingness to accept recycled water being incorporated in the regions, water

management plans and to measure their affordability and the willingness to pay for treating wastewater.

The methodology that was followed to achieve the objectives of this study is summarized in the following points:

4.2.1 Data collection

The related data collected from secondary sources such as: books, journals, work papers, historical data and results, and scientific references etc… The primary source of the data will be the questionnaire. The researcher designed and prepare the questionnaire consulting a group of farmers, as the questionnaire must have its axes relevant to the study.

4.2.2 Field Survey

During the study, the sample was selected as a simple sample from farmers, which discussed the effect of changes in their crops in case after the sea water desalination plant is existed. And to expect the future water consumption leading to understand the future situation of water desalination.

4.2.3 Questionnaire Design

A questionnaire according to Saunders et al. (2003) is a method of collecting data that consists of a series of questions and other prompts for the purpose of gathering information from respondents. According to Johnson and Duberley (2000), a questionnaire is a structured technique for data collection that includes a series of questions, written or verbal, that a respondent answers.

The questionnaire focused on the target group "People working in agriculture", their ability to fill the questionnaire simplicity and away from the difficult terms as possible and clarify some words with examples. The focus was to make the questionnaire as short to obtain more accurate results, away from boredom in filling the questionnaire, therefore focused on optional questions to achieve that.

The researcher followed two types of questions:

1. Closed questions where the researcher asks a closed question, options are selected as examples (yes or no) or closed multi-choices.
2. Open closed questions where the researcher asks a closed question, options are followed in the open question required additional information of the applicant.

4.2.4 Questionnaire Content

1. General information: aims to collect information on the quality and nature of the farms, including the level of age, education, years of practical experience in agriculture, and the area of agricultural tenure and ownership.

2. Effect of a wastewater disposal system on the surrounding environment: aims to identify the methods of disposal of the current wastewater and measuring its effect in cases of the use of random disposal methods and the consequences thereof, such as the diseases that cause them.

3. Patterns of agriculture and land use: aims to measure land use and determining the water needs of agricultural activities using irrigated agriculture as well as identifying obstacles facing farmers in irrigation.

4. Measurement of the wishes of workers in the agricultural sector in the use of treated wastewater: aims to study the economic, cultural and social aspects of the possibility of accepting or rejecting the reuse of wastewater treated wastewater in agriculture.

5. Measuring environmental awareness: aims to assess the environmental impact and environmental value of farmers.

4.2.5 Sample Size

Study sample is a subset of the population selected to participate in a research study and its size refers to the number of the elements to be included in a study (Tayie, 2005; Zikmund et al., 2009). The aim of determining an adequate sample size is to estimate the population prevalence with a good precision (Naing et al., 2006). It is extremely rarely possible to conduct full population surveys so that, a sample can be chosen from the study population that is commonly referred to as the 'target population' (Malhotra and Birks, 2007). The most advantage of using sample is that it is less time and less costly than collecting data from all of the population. Otherwise, the disadvantage of using sample is that the selected sample may not adequately representative of the population and the results obtained from it cannot be generalized (Tayie, 2005; Marczyk et al., 2005). The principles of statistical sampling, which guarantee a representative sample are employed for economy and speed (Fellows and Liu, 2008).

Several factors can influence the size of the required sample for a study, including the purpose of the study, population size, sample sizes used in similar studies, the risk of selecting a "bad" sample, and the allowable sampling error and resource constraints (Malhotra and Birks, 2007; Israel, 2013). A statistical calculation approach has been used in this study to calculate the required sample size. The following formula was used to determine the sample size of unlimited population (De Vaus, 2002; Israel, 2013; Creative research system, 2014).

To calculate the sample size for this study, a statistical calculation was used. The following formula was used to determine the sample size of unlimited population (Creative research system, 2008).

$$SS = \frac{Z^2 \times P \times (1-P)}{C^2}$$

✓ SS = Sample Size.

✓ Z = Z Value (e.g. 1.96 for 95% confidence level of $\alpha = 0.05$).

✓ P = Percentage picking a choice, expressed as decimal, (0.50 used for sample size needed). Its value taken as 50% or 0.5 as it would lead to a larger sample size (Naing et al., 2006).

✓ C = Often, an 'acceptable' margin of error used by survey researchers falls between 4% and 8% of the 95% confidence level (DataStar, 2008), because the population is not high, therefore a maximum error of estimation (0.08) is a reasonable choice.

On the basis of the mentioned reasons, sample size for this study can be calculated as follows:

$$SS = \frac{1.96^2 \times 0.5 \times (1-0.5)}{0.08^2} = 150$$

The above sample size formula is valid if the calculated sample size is smaller than or equal to 5% of the population size (n/N ≤0.05) If this proportion is larger than 5% (n/N >0.05), we need to use the formula with finite population correction (Bartlet et al., 2001; Naing et al., 2006), using the following formula:

$$New \ \ SS = \frac{SS}{1 + \frac{SS-1}{pop}}$$

✓ New SS = Corrected sample size.
✓ Pop = Population size.

The population was "3452" agricultural holder (PCBC, 2016), and the ratio between the obtained sample size and the population equals to (150/3452) = 0.043 which is less than 0.05.

So that, in this study, 150 questionnaires need to be distributed to farmers in Rafah governorate, but researcher, distributed 160 questionnaires, because some questionnaires may be defected.

4.2.6 Pilot Study

Naoum (2012) argued that, pilot study provides a trial run for the questionnaire, which will be used to test the clarity, quality, time scale and bias of the questionnaire by testing the technique that used to collect the data, testing the wording of the questions, identifying ambiguous questions, irrelevant information, , etc. It is worth noting that, pilot study or field pretest of a questionnaire often solves most problems with closed ended questions (Tayie, 2005).

Before preparing the final version of the questionnaire to examine the degree of understanding of the questionnaire from the respondents, five questionnaires were tested by the farmers. In general, the respondents agreed that the questionnaire is easily understood and some modification to the questionnaire was conducted to be clearer and the final questionnaire was prepared after taking the results of the pilot study into account and the questionnaire became ready to be distributed to the selected sample.

4.2.7 Statistical Analysis

Once the questions are collected, it should be processed and analyzed in accordance with the outline laid down for the purpose at the time of developing the research plan. The data should be presented in a well-structured and easy way (Biggam, 2015). Kothari (2004) defined data analysis as "the computation of certain measures along with searching for patterns of relationship that exist amongst the data-groups".

The overall goal of data analysis is to arrive at a general understanding of the phenomenon under study (Tayie, 2005). The computerized programs EXCEL and SPSS were used as the data analysis tool to help tabulate data and analysis.

Chapter Five

Results and Discussion

Chapter Five

Results and Discussion

The main objective of this study is to investigate the quality of RWWTP effluent, and to evaluate the impact of using treated wastewater on quality of resources and efficiency of farming activities. To achieve the objectives of the study, the national and international reuse guidelines were reviewed and compared with the case in RWWTP. The previous chapters presented the methodology that was implemented to achieve results. This chapter will analyze the results of wastewater reuse for agricultural irrigation and study the need of farmers to use treated wastewater.

Finally, regional and international experiences are highlighted to bridge the gap between the farmers and the researchers to understand and practically use the treated effluent for irrigation of their plants under the monitoring of the relevant institutions.

5.1 Part I: Quality Measurement

The average daily flow quantities received from RWWTP reach 12,000 m^3/d, existing RWWTP provide only partial treatment of the wastewater concerning organic matter, due to inadequate treatment system performance is the inadequate design and limited electricity supply. The influent BOD, COD, TSS, TKN, NO_3, pH, and EC account for 600, 1300, 596, 182, 0.4 (mg/l), 8.1, and 4600 µs/cm.

A range of concentrations of effluent treated wastewater was tested (Physical, chemical, biological, and heavy metals) for samples taken from RWWTP effluent. The result shown in Table (5.1) was evaluated according to the guidelines and standards of local, regional and international references (FAO, 1992 & PS 742/2003) guidelines.

Table (5.1): Result of effluent from RWWTP comparison with standards

NO.	Parameter	Unit	Date of test	TWW effluent of RWWTP	FAO 1992	PS 742/2003*
1	BOD$_5$	(mg/l)	10/10/2017	110	20-30	45-60
2	COD	(mg/l)	10/10/2017	250	50-60	150-200
3	NH$_4$	(mg/l)	10/10/2017	126.8	40	NA

NO.	Parameter	Unit	Date of test	TWW effluent of RWWTP	FAO 1992	PS 742/2003*
4	TKN	(mg/l)	10/10/2017	107.7	NA	50
5	NO_3	(mg/l)	10/10/2017	0.225	50	50
6	P	(mg/l)	10/10/2017	17.9	30	30
7	Na^+	(mg/l)	10/10/2017	543	900	460
8	Ca^{++}	(mg/l)	10/10/2017	89	400	400
9	Mg^{++}	(mg/l)	10/10/2017	88	60	60
10	Cl	(mg/l)	10/10/2017	786	1000	500
11	SAR**	(meq/l)	-	9.73	0-15	9
12	TSS	(mg/l)	10/10/2017	137	50	50
13	FC	(CFU /100ml)	10/10/2017	620,000 /100ml	<1000/ 100ml	<1000/100ml
14	TDS**	(mg/l)	-	2976	500-2000	1500
15	pH	Value	10/10/2017	8.2	6.5-8.4	6-9
16	EC	(μs/cm)	10/10/2017	4650	0-3000	2500
17	Cd	ppm***	10/10/2017	<0.003	10	10
18	Pb	ppm***	10/10/2017	<0.001	93	100
19	Cu	ppm***	10/10/2017	19.9	43	200

∗ PS-742-2003 for dry fodder irrigation.   *** ppm = (mg/l) = 1000 ppb
∗∗ Parameter was calculated   NA: cannot give a relevant.

5.1.1 Physical Properties

5.1.1.1 Hydrogen Potential (pH Value)

pH is an indicator expression of the intensity of the basic or acid of a liquid; ranges from 0 to 14, where 0 is the most acid and 7 is neutral. Natural water usually has a PH value between 6.5 and 8.4 (see Figure 5.1) (Pescod, 1992), but usually is seldom a problem by itself. Normally, pH is a routine measurement in irrigation water quality assessment. Water pH is important for plant management because it affects the availability of nutrients and the efficacy of insecticides. According to the results shown in Table (5.1), effluent treated wastewater pH of 8.2 was found desirable, a pH range from 6.5 to 8.4 is an effluent quality treated wastewater for irrigation according to FAO-1992 guidelines, and a pH range of 6-9 is desirable for

effluent quality for irrigation according to the PS-742-2003. Therefore, the used treated wastewater is suitable for irrigation in term of pH.
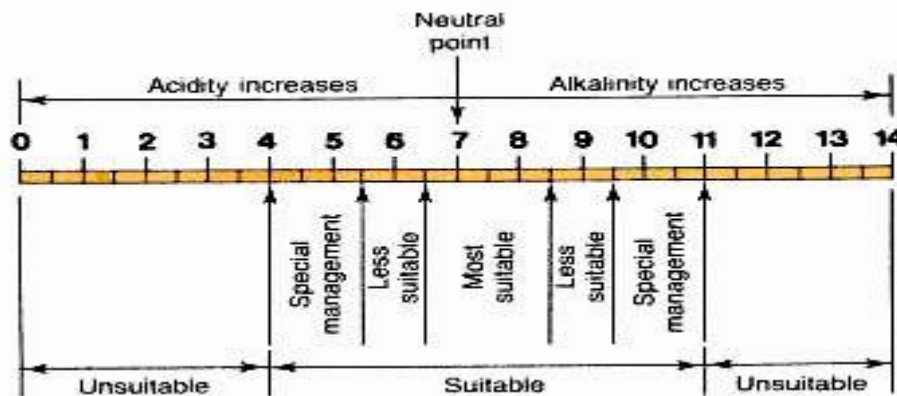
Figure (5.1): pH scale (Pescod, 1992)

5.1.1.2 Salinity hazard

Salinity is the saltiness or amount of dissolved salt in a water are derived from conductivity, the salinity of the effluent could be measured by two parameters TDS and EC. Refer to the Total Dissolve Solids content can be calculated from Electrical Conductivity (EC) is the numerical expression of the ability of an aqueous solution to carry an electric current. There is a direct relationship between Electrical Conductivity and TDS. This makes determination of TDS easier as EC, which can be measured readily with an instrument.

TDS = 0.64 EC, where: EC = Electrical Conductivity (μs/cm). TDS = Total Dissolved Solids (mg/l). EC = 4650 μs/cm.

$$TDS = 4650 \times 0.64 = 2976 \text{ mg/l.}$$

According to (EPA, 2003) EC values are still in the usual range of salinity where the critical value of applied water should not increase 3000 μs/cm.

(EPA, 2003) guidelines divided the applied wastewater into five main classes based on EC and TDS values as in Table (5.2). The range of salinity is classified as 4, where the effluent should be used for special tolerant crops with care of drainage system.

The results of EC and TDS effluent value, Based on (FAO, 1992) guidelines for salinity concentrations is shown in Table (5.3), current salinity for RWWTP has a severe degree of restriction on use. (PS 742/2003) recommends TDS of 1500 mg/l for treating wastewater to be used for irrigation, and excessive salinity may damage

some crops. Salt concentration improves soil absorption, reduces plant uptake of soil nutrients, and reduces soil fertility (Mbarki et al., 2017).

Table (5.2): Salinity classes of irrigation waters and salt tolerant plants (EPA, 2003)

Class	TDS (mg/l)	EC (µs/cm)	Comments
1	0 -175	0 - 270	Can be used for most crops on most soils with all methods of water applied with little likelihood that salinity problem will develop. Some leaching is required and this will occur under the normal irrigation.
2	175 - 500	270 -780	Used if a moderate amount of leaching occur. Plant of moderate salt tolerance can grow, usually without salinity management. Sprinkler irrigation can cause leaf scorch on salt sensitive crops.
3	500 - 1500	780 - 2340	The more saline water in this class should be used with restricted drainage. Even with adequate drainage best practice management controls for salinity may be require and plant salt tolerance must be considered.
4	1500 - 3500	2340 - 5470	Soil must be permeable. Water must be applied in excess for leaching and salt tolerant plant should be selected.
5	>3500	>5470	Not suitable for irrigation except on well drain soil under good management, especially in relation to leaching to salt tolerant crops or emergency use.

Table (5.3): FAO Guidelines for interpretations of water quality for irrigation (Pescod, 1992)

Potential irrigation Problem	Units	Degree of restriction on use			Fresh water
		None	Slight to moderate	severe	
Salinity					
EC	dS/m	<0.7	0.7 - 3.0	> 3.0	2.83
TDS	mg/l	<450	450 - 2000	> 2000	1700

5.1.2 Chemical Properties

5.1.2.1 Sodium (Na) Hazard

Sodic water is water with high concentration of sodium relative to the concentration of calcium and magnesium. Result of effluent RWWTP showed that sodium Na+ level of the applied water concentration of RWW (543 mg/l) exceeded

the maximum level assigned according to the (FAO, 1992 & PS 742/2003) guidelines which are 460mg/l in (PS-742-2003) and 900 mg/l in (FAO, 1992).

According to PS-742-2003, type of TWW unsuitable for irrigation due to the high Na content. The higher concentration of Na in wastewater is due to household products for laundry, kitchen, bath, and cleaning (Shomar et al., 2005).

Also sodium concentration is associated with chloride (CL) concentration which is originally high in the Gaza strip ground water due to seawater intrusion (Shomar et al., 2010).

Irrigation water containing large amounts of sodium is of special concern due to sodium's effects on the soil and poses a sodium hazard; excess sodium in waters produces the undesirable effects of changing soil properties and reducing soil permeability. Hence, the assessment of sodium concentration is necessary while considering the suitability for irrigation.

5.1.2.2 Hardness of Water (calcium and magnesium)

Water hardness is an aesthetic quality of water. It is caused mostly by the minerals calcium and magnesium, but classified or measured based on the equivalence of calcium carbonate. The following Table (5.4) shows hardness classification.

Value of calcium concentration at RWWTP was 89 mg/l for the TWW, therefore thw Ca level is still in the acceptable range according to the (FAO, 1992 & PS- 742/2003) guidelines as the value recommends of Ca concentration is 0 - 400 mg/l.

Value of Magnesium concentration at RWWTP was 88 mg/l for the TWW. While the values of Mg exceed the maximum allowable value 60 mg/l of guidelines according to (FAO, 1992 & PS 742/2003) guidelines.

Calcium and magnesium are normally the only significant minerals that cause hardness, the degree of hardness becomes greater as the calcium and magnesium content increases, the hardness can calculate by equation (APHA, 2005):

Ca [mg/l as $CaCO_3$] =89*(50/20) =222.5 mg/l as $CaCO_3$

Mg [mg/l as $CaCO_3$] =88*(50/20) =366.7 mg/l as $CaCO_3$

Total Hardness (mg/l as $CaCO_3$) = 222.5 [Ca, mg/l] + 366.7 [Mg, mg/l] = 589 mg/l.

According to Table (5.4), because total hardness for RWWTP effluent equals 589 mg/l as CaCO3. Also treated wastewater is assumed to be very hard water as total hardness.

Table (5.4): Hardness classification Ca Co$_3$

Classification	Total Hardness as mg/l of CaCO$_3$
Soft Water	0 - 60
Moderately Hard	61 - 120
Hard	121 - 180
Very Hard	181 or above

High concentration of Ca and Mg ions in irrigation water can increase soil pH, resulting in reducing of the availability of phosphorous P (Al-Shammiri et al., 2005). But they are also essential plant nutrients.

5.1.2.3 Sodium Adsorption Ratio (SAR)

SAR was widely accepted by researchers to evaluate the potential soil degradation caused by relatively high sodium content in the soil profile. Sodium hazard is also usually expressed in terms of the sodium adsorption ratio (SAR). SAR is calculated from the ratio of sodium to calcium and magnesium by using the following equation:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} = 9.73$$

Where: Na=543/23=23.61 meq/l, Ca=89/20=4.45 meq/l, Mg=88/12=7.33 meq/l.

SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard.

High Sodium Adsorption Ratios reduce the infiltration rate of water into the soil. The value of SAR for TWW of RWWTP was 9.73 meq/l, slightly exceed the maximum allowable value 9 meq/l, acceptable according to (FAO, 1992) guidelines standards. Which the value of SAR should not exceed the permissible level of 10 to have Stable Soil, classified based on SAR as excellent (<10), Good (10-18), Doubtful (18-26) and Unsuitable (>26) (Pescod, 1992).

5.1.2.4 Nitrate (NO$_3$)

Nitrate is naturally occurring ions that are part of the nitrogen cycle, the nitrate ion (NO3) is the stable form of combined nitrogen for oxygenated systems (Tyagi et al., 2018).

Results indicated that Nitrate NO3 values was 0.225 mg/l for TWW lower than usual limits 50 mg/l, stated by (FAO, 1992 & PS 742/2003).

The reason of which nitrate in TWW is within the permissible level and lower than the source water because during any biological treatment process, the total nitrogen is converted in cell synthesis by ammonification, in addition to that removed during the sedimentation processes (Horan, 1989).

Moreover, nitrate plays essential role in plant growth, therefore, the limitations are not restricted, but in some plant growth stages nitrate is not preferable.

5.1.2.5 Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl Nitrogen (TKN) is an analysis to determine both the organic nitrogen and the ammonia nitrogen. The analysis involves a preliminary digestion to convert the organic nitrogen to ammonia, then distillation of the total ammonia into an acid absorbing solution and determination of the ammonia by an appropriate method.

According to the EPA definition, Total Nitrogen equals TKN plus nitrate plus nitrite (Redmond et al., 2014).

Total Kjeldahl Nitrogen = Organic Nitrogen + Ammonia Nitrogen

The values of Total Kjeldahl Nitrogen (TKN) were 107.7 mg/l for TWW effluent of RWWTP, these results are in excess of the acceptable range assigned (PS 224/2003) reference standards for irrigated water quality which reported to be 50 mg/l.

5.1.2.6 Total Suspended Solid (TSS)

TSS value for effluent TWW was 137 mg/l, which is higher than usual limits 50 mg/l, stated by (FAO, 1992 & PS 742/2003). Total suspended solids (TSS) gives a measure of the turbidity of the TWW, this value of TSS continues to be high stages and leading to high maintenance cost of RWWTP and cause plugging in irrigation systems, in addition affect soil infiltration.

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5.1.2.7 Ammonium (NH$_4$)

It was clearly noticed NH$_4$ value for TWW effluent was 126.8 mg/l, these results higher than (FAO, 1992) standard range (0 - 40) mg/l.

5.1.2.8 Phosphorus (P)

Phosphorus is absorbed by plant roots in the orthophosphate form, the values of phosphorus was 17.9 mg/l for TWW of RWWTP. The major source of phosphorus in wastewater is from human excreta and synthetic detergent. According to (FAO, 1992 & PS 742/2003), the maximum permissible Phosphorus value is 30 mg/l. Results indicated that P was within guidelines values, these values indicate low degree of detergent exist in TWW within allowable range.

5.1.2.9 Chloride (Cl)

The value of Cl for TWW of RWWTP was 786 mg/l. It was clearly noticed that Cl value for applying wastewater meet the maximum allowable value 1000 mg/l according to (FAO, 1992) guidelines standards, but it was exceeded the maximum concentration of Cl was 500 mg/l assigned by (PS 742/2003) guidelines.

Moreover, the salinity of the groundwater generates from the sea water intrusion which characterized by high Cl and Na ions.

The sensitivity level of chloride concentration in water for different plant groups is shown in Table (5.5), chloride concentration of treated wastewater is 786 mg/l, which also makes it suitable only of tolerant crops. According to (PS 742/2003) the recommends chloride concentration for treating wastewater to be used for irrigation is 500 mg/l as shown in table (5.1). Treated wastewater has a high concentration of chloride because it is not removed by wastewater treatment.

Table (5.5): Different Sensitivity Crop Groups for Chloride Concentration Used for Irrigation (ANZECC, 1992)

Sensitivity	Chloride(mg/l)	Affected crop
Sensitive	<178	Almond, apricot, plum
Moderately sensitive	178 - 355	Grape, pepper, potato, tomato
Moderately tolerant	355 - 710	Alfalfa, barley, corn, cucumber
Tolerant	>710	Cauliflower, cotton, sorghum, sunflower

5.1.2.10 Biochemical and Chemical Oxygen Demands (BOD$_5$ and COD)

The COD analyses measure the chemical decomposition of organic and inorganic contaminants, dissolved or suspended in water, and the BOD, which gives the amount of total biodegradable organic substances in the water sample, measures the rate of the activities of bacteria and other aerobic microorganisms, which feed on organic matter in the presence of oxygen.

The BOD$_5$ values for TWW of RWWTP was 110 mg/l, Also COD values was 250 mg/l. In comparison to both value of BOD and COD to meet (FAO, 1992 & PS 742/2003), these results is excess the acceptable range.

5.1.2.11 Biological Parameters

Fecal & total coliform (FC) was investigated as indicator parameters for biological characteristics of wastewater. Fecal Coliforms (FC) are Coliforms that can ferment lactose at the higher temperature of 44.5 °C. They are better indicators of fecal pollution than total Coliforms, but some fecal Coliforms (especially in tropical and subtropical areas) are not exclusively fecal in origin (World Bank, 2010).

Results of treated wastewater of RWWTP show that fecal Coliform Bacteria equal 620,000 CFU/100 ml. That means high risk of pathogen presence, and it is much higher than (FAO, 1992 & PS 742/2003) standards.

5.1.2.12 Heavy Metal (HM)

Lead (Pb) in wastewater comes from recycled batteries, storage tank linings and corrosive liquid tanks paints, antibacterial and wood preservatives, in addition to petrol. But Cadmium (Cd) comes from industrial sources such as galvanizing. Household sources include disposal batteries, traffic sources such as tires and oil, and from farming sources because cadmium is used to treat poultry infected with parasitic worms (Dojlido and Best, 1993). The results of effluent Cd, Pb, Cu are in the range of (FAO, 1992 & PS 742/2003) standards).

5.1.3 Relationship between Quality of RWWTP Effluent and the Palestinian Reuse Standards

The current effluent of RWWTP discharge into the sea, therefore, to present the alternative solution and study is applicable.

Under the water scarce situation in GS, reuse of treated wastewater for other purposes is strongly encouraged by PWA. Reuse activities for the reclaimed

wastewater in Palestine are: irrigation of crops, groundwater recharges and reuse for industrial purposes.

Where Table (5.6) shows the value of effluent treated wastewater quality of the RWWTP, It is concluded that the produced wastewater from RWWTP does not meet the minimum quality criteria Class D standards, concerning BOD and TSS.

Table (5.6): Comparison between the RWWTP effluent and the PS 742/2033 reuse standard classification

WWTP	BOD$_5$			TSS (mg/l)		
	Effluent	Class C	Class D	Effluent	Class C	Class D
Rafah	<u>110</u>	40	60	<u>137</u>	50	90

Based on the Palestinian Standards for the purpose of this study, the researcher only considered the main parameters defining the pollution and which are necessary for the dimensioning of any additional new works for further in RWWTP. The parameters are: BOD, COD, TSS, TKN, NH4, NO$_3$, P and Fecal Coliforms. Table (5.7) presents the values of the main dimensioning parameters, depending on the reuse of the treated wastewater.

Table (5.7): Main parameters based on Palestinian wastewater reuse standards

Parameter (mg/l)	Almond Trees	Olive Trees	Citrus Trees	Forest Trees	Industrial crops	Gardens, Recreation	Feed irrigation green	Feed irrigation dried	GW recharge infiltration	Disposal to the sea
BOD	45	45	45	60	60	40	45	60	20	40
COD	90	90	120	120	80	80	90	120	50	100
TSS	40	40	40	50	50	30	40	50	50	60
NO$_3$	50	50	50	50	50	50	50	50	30	45
TKN	100	100	100	100	100	45	100	100	25	50
P	30	30	30	30	30	30	30	30	15	10
NTU	5	5	5	5	5	5	5	5	2	-
F.C (CFU/ 100ml)	200	200	200	200	200	200	200	200	200	200

5.1.4 Agriculture Water Demand

Agricultural lands in the Rafah governorate are limited and unknown area in the coming years because of the limitation of the land and the unregistered governmental lands, populations need more residential lands, and there are several other factors affected on the agricultural sector. As a result, it was considered that the area of agriculture land will not change, the researcher neglected the unused agricultural land, and types of crops remain constant during the study period. Through the report by the MOA and MOR, researcher obtain the area of agricultural land in Rafah governorate and the types of agriculture used in the governorate, according to the Tables (5.8), the researcher calculates the amount of yearly water consumption for agriculture land.

Where the total area of Rafah governorate 64,000 donum the proportion of classified in the agriculture 15.40%, which equivalent of 9,856 donum were distributed according to the following table (5.8).

Table (5.8): Area of crop type in Rafah governorate (MOA and MOR, 2018)

| Crop | Production (ton) | Area (dunam) | Water requirement for crop | | |
			m³/dunam (yearly)	$\times 10^6$ m³/year	% of total
Olive	327	2960	550	1.628	41.36%
Almond(Hard)	165	1100	300	0.330	8.38%
Valencia Orange	1962	654	900	0.589	14.95%
Date	285	475	850	0.404	10.26%
Aloe	320	320	0	0.000	0.00%
Guava	690	280	920	0.258	6.54%
Lemon	324	247	900	0.222	5.65%
Poppy	264	215	900	0.194	4.92%
Peach	125	188	450	0.085	2.15%
Grape	318	175	500	0.088	2.22%
Apple	8	75	650	0.049	1.24%
Fig	26	37	150	0.006	0.14%
Apricot	6	27	450	0.012	0.31%
Grapefruit	60	25	900	0.023	0.57%

Crop	Production (ton)	Area (dunam)	Water requirement for crop		
			m³/dunam (yearly)	$\times 10^6$ m³/year	% of total
Others	95	38	900	0.034	0.87%
Other Citrus	38	19	900	0.017	0.43%
*Agricultural land not cultivated	3,021		0	0.000	0.00%
Total	5,013	9,856		3.936	100.00%

* Agricultural land not cultivated: according to the master plan of rafah is classified as agricultural land but mostly blank.

5.2 Part II: Questionnaire Results

The results obtained from the field survey through the questionnaires filled by the farmers in the Rafah governorate who will benefit from a reuse project in the Rafah area in the GS, the required sample consists of 150 responders from the Rafah governorate. The researcher, distributed 160 questionnaires, but when collect questionnaires find it 153 questionnaires, and there 8 questionnaires not valid to statically analysis, therefore the total of questionnaires become 145, the analysis was done by using EXCEL and SPSS softwares.

5.2.1 General Information

Table (5.9): Survey results about general information

General information	Frequency	Percent
1- Educational level		
Uneducated	23	15.9%
Elementary School	21	14.5%
Preparatory School	31	21.4%
Secondary	33	22.8%
Diploma	28	19.3%
University graduate and over	9	6.2%
2- Age group		
Less than 18 years	18	12.4%
From 18 to less than 30 years	46	31.7%
From 30 to less than 45 years	67	46.2%
45 years and over	14	9.7%
3- Number of family members working in agriculture		
Less than 3	26	17.9%
From 3 to less than 5	40	27.6%
From 5 to less than 10	65	44.8%
10 and over	14	9.7%
4- Total monthly income of the family		

General information	Frequency	Percent
Less than 600 NIS	19	13.1%
From 600 to less than 1,000 NIS	45	31.0%
From 1,000 to less than 2,000 NIS	58	40.0%
More than 2000 NIS	23	15.9%
5- Is land the only source of income for your family		
Yes	87	60.0%
No	25	17.2%
Sometimes	33	22.8%
6- Total monthly income of the family		
Less than 600 NIS	19	13.1%
From 600 to less than 1,000 NIS	45	31.0%
From 1,000 to less than 2,000 NIS	58	40.0%
More than 2000 NIS	23	15.9%
7- Farmer's relationship with the farm		
Farm owner	34	23.4%
Partner	22	15.2%
Tenant	42	29.0%
Worker	47	32.4%
8- Area of land owned (dunums)		
Less than 5 dunums	63	43.4%
From 5 less than 8 dunums	42	29.0%
From 8 to less than 12 dunums	29	20.0%
More than 12 dunums	11	7.6%
9- Type of land ownership		
Government land	12	8.3%
TABO land	102	70.3%
Land of endowments	7	4.8%
Sheva land	19	13.1%
hebal land (un-registed land)	2	1.4%
I do not know	3	2.1%

5.2.2 Effect of Wastewater Disposal System on the Surrounding Environment

5.2.2.1 Support the Existence of a sewage Collection System in Rafah

Table (5.10) shows almost all of the respondent (91.7%) have realized the importance of having the wastewater collection system. A few respondents (6.2%) of respondents did not support this system, this percent it less and not realized the importance. While (2.1%) of respondents do not know. The population is clearly convinced of the need for wastewater collection system.

Table (5.10): Support the existence of a sewage collection system in Rafah

Do you support the existence of a sewage collection system in Rafah?		
Choices	Frequency	Percentage
Supporter	133	91.7%
Not supportive	9	6.2%
I do not know	3	2.1%

5.2.2.2 Methods of Disposal of Wastewater in Rafah Governorate

Four methods were tested. Table (5.11) shows that (57.2%) of the respondents mentioned that they used wastewater network, the most common method is wastewater network, known wastewater network coverage (82%) of Rafah residents are connected to the existing sewage system. (26.9%) used cesspit tanks, this method is common in the absence of a sewage system, and others (15.9%) let go runoff in open channels. None of any respondents stated used septic tanks (non-infiltration), the reason is because it is very expensive.

Table (5.11): Methods of disposal from wastewater in Rafah governorate

How do people dispose wastewater in your area?		
Choices	Frequency	Percentage
Cesspit tanks	39	26.9%
Septic tanks (non-infiltration)	0	0.0%
Wastewater network	83	57.2%
Runoff in open channels	23	15.9%

5.2.2.3 Effects of Random Disposal of Wastewater on Public Health and Agricultural Land

The results in Table (5.12) showed that (82.1%) respondents of the statistical sample believe that the disposal of water in a random way, affects the environment and public health, and that (12.4%) not support exist effects, others (5.5%) do not know. The risks of untreated wastewater to health and the environment include the presence of bacteria, viruses and parasites that cause many serious diseases.

Table (5.12): Think about the random disposal of wastewater affects public health and agricultural land

Do you think that the random disposal of wastewater affects public health and agricultural land?		
Choices	Frequency	Percentage
Yes	119	82.1%
No	18	12.4%
I do not know	8	5.5%

5.2.2.4 Problems do Residents of Rafah Governorate Suffer due to Wastewater Disposal

The residents of Rafah face environmental and aesthetic problems present in Table (5.13) due to wastewater, (29%) of the statistical sample suffer from mosquitoes problem, (18.6%) of the sample was affected by odor problem. While wastewater rash represent (15.9%). There are who suffer from all these problems represent (31.7%). Others (4.8%) not suffering from any problem related from wastewater disposal.

Table (5.13): Problems facing the environment in the Rafah governorate due to wastewater disposal

Which of the problems do residents of your area suffer from wastewater disposal?		
Choices	Frequency	Percentage
Mosquitoes	42	29.0%
Bad smell	27	18.6%
Street sewage rash	23	15.9%
All of this	46	31.7%
Nothing of this	7	4.8%

5.2.3 Patterns of Agriculture and Land Use

5.2.3.1 Cultivate the Land

The results Table (5.14) shows that (85.5%) of the statistical sample that cultivate the land due to the lack of employment opportunities in government jobs and industry in the current difficult economic conditions. Those who sometimes cultivate land, which accounts for (11.7%) of the land, consider it secondary after work. Others (2.8%) not cultivate the land because another income source.

Table (5.14): Farmers who cultivate the land

Do you cultivate the land?		
Choices	Frequency	Percentage
Yes	124	85.5%
No	4	2.8%
Sometimes	17	11.7%

5.2.3.2 System of Irrigated Agriculture

The results showed that (68.3%) respondents of the statistical sample depend on the irrigated agriculture system, and that (19.3%) sometimes, others (12.4%) rely in rainfed agriculture. The statistical sample reported that the prevailing pattern of agriculture in the region is irrigated agriculture due to the fluctuation of the rainy season and the farmer's dependence on irrigation from the private agricultural wells that own and selling water from these wells to the neighboring peoples.

Table (5.15): Dependence in irrigated agriculture system

Do you rely on the system of irrigated agriculture?		
Choices	Frequency	Percentage
Yes	99	68.3%
No	28	19.3%
Sometimes	18	12.4%

5.2.3.3 Irrigation Methods for the Crops

According to the statistical sample, who use irrigated agriculture system, (43.6%) use an irrigation method by hose pipe and (38.5%) use drip irrigation method. While (12%) use the irrigation system of channels. Others (6%) use irrigation by Sprayers.

Table (5.16): Irrigation methods used for the crops

What is the irrigation method for the crops you use?		
Choices	Frequency	Percentage
Irrigation with hose	51	43.6%
Drip	45	38.5%

What is the irrigation method for the crops you use?		
Choices	Frequency	Percentage
Sprayers	7	6.0%
Channels	14	12.0%
Other	0	0.0%

5.2.3.4 Water Sources used for Irrigation

According to the statistical sample, who use irrigated agriculture system includes (64.1%) use Municipal water and (34.2%) use Agricultural wells. Others (1.7%) use rainwater storage.

Table (5.17): water sources used in irrigation

What water sources do you use?		
Choices	Frequency	Percentage
Agricultural wells	40	34.2%
Rainwater storage	2	1.7%
Municipal water	75	64.1%
Treated wastewater	0	0.0%

5.2.3.5 Water Quantity used for Irrigation

According to the statistical sample, those who rely on irrigated agriculture (65.8%) showed that the amount of water used in irrigation (11-20 m^3 per week). (20.5%) need amount (1-10 m^3 per week), while (9.4%) need (21-30m^3 per week), others (4.3%) need (30- 40 m^3 per week).

Table (5.18): Water quantity consumed for irrigation

How much water do you use to irrigate crops?		
Choices	Frequency	Percentage
1-10 m^3	24	20.5%
10- 20 m^3	77	65.8%
20- 30 m^3	11	9.4%
30- 40 m^3	5	4.3%
Over 40 m^3	0	0.0%

5.2.3.6 Reasons that do not use Irrigated Agriculture

According to the statistical sample shown in Table (5.19), (52.4%) of the sample showed that the reason for the lack of orientation of the study population towards irrigated crops, was due to lack of water, while (33.3%) of the statistical sample indicated that it was due to the high financial cost. Water is purchased at high prices, where seedlings and seeds are expensive and sometimes unavailable. While (9.5%) said that they did not desire irrigated agriculture in addition to (4.8%) to other reasons such as water salinity.

Table (5.19): Reasons behind not using irrigated agriculture

If you do not use irrigated agriculture, why?		
Choices	Frequency	Percentage
Lack of water	11	52.4%
High cost	7	33.3%
Do not want to use it	2	9.5%
Other	1	4.8%

5.2.3.7 Lack of Availability of Water Quantities in Year

According to the results of respondents (53.8%) suffer from a shortage of water in the summer season. About (18.6%) of the respondents mentioned suffer from a shortage of water in all days of the year. While (16.6%) of the respondents suffers from a shortage of water in some days of the year. Few respondents (11%) of respondents suffer from a shortage of water in the winter season.

Farmers whose own private agricultural wells suffer from water shortages, which affect the supply of water to agricultural land and the problem increases in the summer due to electricity shortages.

Table (5.20): Lack of availability of water quantities in a season

Suffer from a lack of availability of water quantities in the year?		
Choices	Frequency	Percentage
Summer	78	53.8%
Winter	16	11.0%
All days of the year	27	18.6%

Suffer from a lack of availability of water quantities in the year?		
Choices	Frequency	Percentage
Some days of the year	24	16.6%

5.2.3.8 Type of Fertilizers used in Agriculture

The results of the study showed that (42.1%) of the statistical sample depended on the organic and chemical fertilizers of the crops and (33.1%) are mainly dependent on the use of chemical fertilizers to fertilize the crops. However, chemical fertilizers have negative effects on the environment, soil, water and crops, and their effect is economical due to the high cost of fertilizers. (22.1%) rely on organic fertilizers only, while only (2.8%) of the respondents reported that they do not use any type of fertilizer. It should be noted the use of treated water helps dispense with this fertilizer as it contains the organic materials necessary for crops.

Table (5.21): Type of fertilizers used in agriculture

What is the quality of fertilizers used in agriculture?		
Choices	Frequency	Percentage
Chemical fertilizers	48	33.1%
Organic fertilizers	32	22.1%
Both	61	42.1%
Do not use them	4	2.8%

5.2.4 Measurement of the Wishes of Workers in the Agricultural Sector in the use of Treated Wastewater

5.2.4.1 Types of Crops Grown in Rafah Governorate

The results also show that the most cultivated plants are olive trees with (26.9%), followed by fruit trees with (22.8%), then the vegetables with (16.6%) followed by field crops with (13.1%), followed by Citrus by (9%).

Table (5.22): Types of crops grown in Rafah Governorate

What types of crops do you cultivate?		
Choices	Frequency	Percentage
Field crops	19	13.1%
Fruitful trees	33	22.8%

What types of crops do you cultivate?		
Choices	Frequency	Percentage
Un-fruitless trees	0	0.0%
Vegetables	24	16.6%
Citrus	13	9.0%
Olive	39	26.9%
various crops	17	11.7%

5.2.4.2 Trust that the Municipality Treat Wastewater well

The responders expressed their diffidence that the municipality will treat wastewater effectively; they were split between trusting (58.6%) and not trusting (41.4%) the municipality.

Table (5.23): Trust that the municipality treat wastewater well

Do you trust that the municipality will treat wastewater as well?		
Choices	Frequency	Percentage
Confident	85	58.6%
Not sure	60	41.4%

5.2.4.3 Preferred term to Describe Treated Wastewater

(57.9%) of the responders prefer reclaimed or purified water term, (30.3%) and Reused water term, but few of the responders (11.7%) prefer treated wastewater term. This study is consistent with the study of (Po, et al., 2005), which shows that the preferred term of 50% of the study sample is "purified water", where it appears that the use certain term for re-treated water should be taken into account because it is an influential factor in society's acceptance, this is due to psychological factors where the mind is associated with that treated wastewater is sewage (waste) that has foul odors and causes diseases. The importance of the phrase should be considered in publications and articles on this subject, taking into account the social, psychological, economic and environmental factors of the population of the region that affect population decisions about the acceptance of wastewater projects (Hartley, 2006).

Table (5.24): Preferred term to describe treated wastewater

What term do you prefer to describe treated wastewater?		
Choices	Frequency	Percentage
Reused water	44	30.3%
Treated wastewater	17	11.7%
Reclaimed or purified water	84	57.9%

5.2.4.4 Accepting the use of Treated Wastewater for Irrigation

(80.7%) of the responders support the idea of irrigating cultivated land with treated wastewater; however, only (19.3%) of the responders rejected their use in irrigation.

Economic factors affect the expansion of land cultivation for several reasons, including the high price of water and fertilizers. Therefore, the use of treated water is expected to contribute to the increased agricultural expansion.

Table (5.25): Accepting the use of treated wastewater for irrigation

If the wastewater is treated with a guarantee of its use in irrigating the plants, are you using it to irrigate the cultivated land?		
Choices	Frequency	Percentage
Yes	117	80.7%
No	28	19.3%

5.2.4.5 Reasons behind Rejection of Treated Wastewater for Irrigation

The results of the study showed that the reason for the refusal of the sample to accept the use of treated wastewater in irrigating agricultural crops (which is estimated to 28 persons) is due to (50%) to the psychological reasons, (32.1%) related to religious reasons, (14.3%) related of health risks, while (3.6%) related to cultural reasons, show Table (5.26).

It should be noted psychological factors play a major role in reuse of wastewater, where it at the feeling, when people connect with their minds as raw sewage (hard water in which solids: feces, and urine), showing a negative reaction as a result of their fear of infection or contamination (Po, et al., 2003).

Abu Madi also studied the most important factors that play a role in rejecting farmers in Tunisia and Jordan for the use of treated wastewater: availability of fresh

water, distrust of water quality, psychological factors, religious factors, fear of marketable crops, and concern about the public health impacts (Abu-Madi, et. al., 2003).

Table (5.26): Reasons for not accepting irrigation of agricultural crops with treated wastewater

In case of un-willingness to use treated water for irrigating crops, it is for reasons?		
Choices	Frequency	Percentage
Psychological	14	50.0%
Religious	9	32.1%
Cultural	1	3.6%
Health risks	4	14.3%
Environmental	0	0.0%
All of this	0	0.0%

5.2.4.6 Benefit from Availability of Treated Wastewater to Increase Cultivated Land

(66.9%) of the responders think that the availability of treated wastewater will encourage landowners to increase space cultivated land, while (33.1%) of the responders disagree that.

Table (5.27): Think about availability of treated wastewater will encourage to increase cultivated land

Do you think that the availability of treated wastewater will encourage landowners to increase space cultivated land?		
Choices	Frequency	Percentage
Yes	97	66.9%
No	48	33.1%

5.2.4.7 Accepting of use Sludge from Treated Wastewater as soil Fertilizer

The majority of the respondent (84.8%) agrees with use sludge from treated wastewater as soil fertilizer if it is safe and non-pathogenic, but 12.4% are afraid of use sludge as soil fertilizer, while 2.8% neutral of use.

Table (5.28): Accepting of use sludge from treated wastewater as soil fertilizer

Can you use sludge from treated wastewater as soil fertilizer if it is safe and non-pathogenic?		
Choices	Frequency	Percentage
Yes	123	84.8%
No	18	12.4%
Neutral	4	2.8%

5.2.4.8 Options of using Treated Wastewater

There are various fields can be potential for using treated wastewater. About (62.1%) prefers to use it in agriculture, (28.3%) prefer to use fire extinguishing, (4.8%) prefer to use it in construction, (2.8%) prefer to use it in industry, and (2.1%) prefer in other uses.

The (Bristow, et. al., 2002) study confirms that the result of treated wastewater as a reliable source has increased acceptance, its use in many areas of life, such as industrial uses (such as cooling), irrigation of public gardens, agriculture and indirect population uses. However, the use of treated wastewater into drinking still unacceptable.

Table (5.29): Options of using treated wastewater

What is your opinion best field about using of treated wastewater?		
Choices	Frequency	Percentage
Agriculture	90	62.1%
Construction	7	4.8%
Fire extinguishing	41	28.3%
Industry (ex: Cooling)	4	2.8%
Other uses	3	2.1%

5.2.4.9 Factors Affects of using Treated Wastewater in Irrigation Purposes

There are various factors affecting of using treated wastewater in irrigation purposes. About (57.9%) said that the price of treated wastewater compared to fresh water, (30.3%) factors related to water availability, (5.5%) of responders fear of health risks, (3.4%) depend on the presence of customers to purchase crops irrigated with treated wastewater, and (2.8%) for all previous factors.

Table (5.30): Factors affect of using treated wastewater in irrigation purposes

Which of the causes affects your idea of using treated wastewater for irrigation purposes?		
Choices	Frequency	Percentage
Water availability	44	30.3%
The price of treated wastewater compared to fresh water	84	57.9%
People accept to buy irrigated crops with treated wastewater	5	3.4%
Fear of health risks	8	5.5%
All of the this	4	2.8%
It is not mentioned	0	0.0%

5.2.4.10 Overall Position on the Reuse of Treated Wastewater

(81.4%) of the responders agree to use treated wastewater, but (15.9%) are disagreeing to use treated wastewater, while (2.8%) neutral of use.

Table (5.31): Overall position on the reuse of treated wastewater

Your overall position on the reuse of treated wastewater?		
Choices	Frequency	Percentage
Agree	118	81.4%
Disagree	23	15.9%
Neutral	4	2.8%

5.2.4.11 Crops Expected to be irrigated from Treated Wastewater

Table (5.32) it is clear that the different types of crops can be potential for irrigated from treated wastewater. About (39%) prefer to irrigate of fodder crops, (32.3%) prefer to irrigate olive trees, (16.1%) prefer to irrigate crops not eaten, (7.6%) prefer to irrigate of fruitful trees, and (5.1%) prefer to irrigate vegetables.

Table (5.32): Crops expected to be irrigated from treated wastewater

If you agree to use treated wastewater for irrigation, you prefer to use it in irrigation?		
Choices	Frequency	Percentage
Fodder crops	46	39.0%
Fruitful trees	9	7.6%

If you agree to use treated wastewater for irrigation, you prefer to use it in irrigation?		
Choices	Frequency	Percentage
Vegetables	6	5.1%
Olive	38	32.2%
Crops not eaten	19	16.1%

5.2.4.12 Motivation to use Treated Wastewater

Almost (50%) of the responders agree to use treated wastewater in agriculture for your belief production will increase due to nutrients in wastewater, therefore, appear important the use of treated wastewater to irrigate crops, about (28.8%) of the responders consider treating wastewater as a new sources of water. (6.8%) of the responders believe treated wastewater will available all the time, while the rest (14.4%) agree with all previous.

Table (5.33): Motivation to use treated wastewater

Agree to use treated wastewater in agriculture for my belief?		
Choices	Frequency	Percentage
A new sources of water	34	28.8%
Production will increase due to nutrients in wastewater	59	50.0%
Treated wastewater is available all the time	8	6.8%
All of this	17	14.4%

5.2.4.13 Opinion about Consumption of Agriculture Products Irrigated from Treated Wastewater

(31%) of responders about Opinion in consumption of agriculture products irrigated from treated wastewater, says eat this because they do not harm health and do not conflict with religious teachings, (29%) refuse to eat them never because religious reasons, (26.2%) only eat it if there is no alternative crop irrigated by normal water, (13.8%) refuse to eat it never because it is harmful to health.

Table (5.34): Opinion about consumption of agriculture products irrigated from treated wastewater

If you know that the agricultural products were bought irrigated with treated wastewater, you will?		
Choices	Frequency	Percentage
I refuse to eat it never because it is harmful to health	20	13.8%
I refuse to eat them never because religion reasons	42	29.0%
I eat this because they do not harm health and do not conflict with religious teachings	45	31.0%
I only eat it if there is no alternative crop irrigated by normal water	38	26.2%

5.2.5 Measuring Environmental Awareness

5.2.5.1 Persons who visited of a treatment Plant in Rafah Governorate

(73.1%) of responders not visited of a treatment plant in Rafah governorate, but (26.9%) of responders visited it.

Table (5.35): Persons who visited of a treatment plant in Rafah governorate

Have you ever visited your sewage treatment plant in your area?		
Choices	Frequency	Percentage
Yes	39	26.9%
No	106	73.1%

5.2.5.2 The Advantages of Exist a wastewater Treatment Plant from Responders Opinion.

About (32.4%) say the advantages of exist a wastewater treatment plant can reuse treated wastewater in agriculture, (28.3%) show advantages to minimize the spread of diseases, (19.3%) expected enhance improve health level, but remaining (20%) of respondents Chose all the previous things.

Table (5.36): Advantages of exist a wastewater treatment plant

The advantages of exist a wastewater treatment plant in your area?		
Choices	Frequency	Percentage
Reuse treated wastewater in agriculture	47	32.4%
Minimize the spread of diseases	41	28.3%
Improve health level	28	19.3%

The advantages of exist a wastewater treatment plant in your area?		
Choices	Frequency	Percentage
All of the this	29	20.0%

5.2.5.3 The Disadvantages of having a wastewater Treatment Plant.

About (38.6%) say the disadvantages of having a wastewater treatment plant from responders opinion emission bad smell, (33.8%) says disadvantages wastewater overflow, (15.2%) says a financial burden on the municipality during operation and maintenance, but remaining (12.4%) of respondents chose lack of confidence in the quality of treated wastewater produced.

Table (5.37): Disadvantages of having a wastewater treatment plant

What are the disadvantages of having a treatment plant in your area?		
Choices	Frequency	Percentage
Lack of confidence in the quality of treated wastewater produced	18	12.4%
A financial burden on the municipality during operation and maintenance	22	15.2%
Bad smell	56	38.6%
Wastewater rash	49	33.8%

5.2.5.4 Necessary Inspect the Treated Wastewater in Laboratories Quality.

(87.6%) of responders, says should always necessary make inspect the treated wastewater in laboratories to ensure of quality, but (9.7%) of responders they do not realize the importance of constantly checking, others show need to do it sometimes.

Table (5.38): Necessary make inspect the treated wastewater in laboratories

Do you think it is necessary to continuously inspect the treated wastewater in laboratories to ensure of quality that it is suitable for irrigating crops?		
Choices	Frequency	Percentage
Yes	127	87.6%
I do not know	14	9.7%
Sometimes	4	2.8%

5.2.5.5 Knowledge about Imported Crops from Outside the Gaza Strip Irrigated with Treated Wastewater.

(80.7%) of responders they know that crops that come from outside the Gaza Strip and from Israel are specifically irrigated from treated wastewater, but (19.3%) of responders They know that crops that come from outside the Gaza Strip and from Israel are specifically irrigated from treated wastewater.

Table (5.39): Knowledge about importing crops irrigated with treated wastewater

Do you know that most of the agricultural crops that come from Israel are irrigated with treated wastewater?		
Choices	Frequency	Percentage
Yes	117	80.7%
No	28	19.3%

5.2.5.6 Buy and Consumption of Products when it is defined as Irrigated from Treated Wastewater.

(53.6%) of the responders stop consumption of products when it is defined as irrigated from treated wastewater, but (46.4%) will consumption of products when it is defined as irrigated from treated wastewater.

Table (5.40): Consumption of products when it is defined as irrigated from treated wastewater

If the previous answer is not, and you know now that it is being irrigated from treated wastewater, will you stop consuming these products?		
Choices	Frequency	Percentage
Yes	13	46.4%
No	15	53.6%

5.2.5.7 The Importance of the need to Explanation that Proves non Harmless from the use of Treated Wastewater to Irrigate Crops

(75.9%) of the responders need to explain that proves harmless from the use of treated wastewater to irrigate crops, but (24.1%) not need any explanation that proves harmless from the use of treated wastewater to irrigate crops.

Table (5.41): Need to explanation that proves the non harmless from the use of treated wastewater

Do you think that you need an explanation that proves the non harmless from the use of treated wastewater to irrigate crops?		
Choices	Frequency	Percentage
Yes	110	75.9%
No	35	24.1%

5.2.5.8 Have you participated in Awareness Programs on Wastewater Reuse for Crop Irrigation?

The highest of responders is in the Rafah governorate, about (94.5%) were not participated in awareness programs on wastewater reuse for crop irrigation, but (5.5%) of responders were participating in awareness programs on wastewater reuse for crop irrigation.

Table (5.42): Participated in awareness programs on wastewater reuse

Have you participated in awareness programs on wastewater reuse in irrigation of crops?		
Choices	Frequency	Percentage
Yes	8	5.5%
No	137	94.5%

5.2.5.9 Appropriate Price of Cubic Meter for Treated Wastewater in Agricultural use

The results show that the majority of the respondent 60% are willing to pay 0.2 NIS, while about (30.3%) of the respondent are not willing to pay any money, Only (9.7%) of the respondent is willing to pay 0.4 NIS and, none of them are willing to pay more than 0.4 NIS per a cubic meter for using treated wastewater for irrigation as indicated in Table (5.43).

Table (5.43): Appropriate price of cubic meter for treated wastewater

What do you think is the right price for cubic meter from treated wastewater in agricultural use?		
Choices	Frequency	Percentage
Zero	44	30.3%
0.2 NIS	87	60.0%

What do you think is the right price for cubic meter from treated wastewater in agricultural use?		
Choices	Frequency	Percentage
0.4 NIS	14	9.7%
0.5 NIS	0	0.0%
Other	0	0.0%

5.2.5.10 Accepted to Participate in Reuse Awareness Programs

(78.6%) of the responders willing to participate in environmental awareness programs to reuse treated wastewater; however, only (21.4%) of the respondents were not interested in participating in awareness programs.

Table (5.44): Accepted to participate in environmental awareness programs

Are you willing to participate in environmental awareness programs to reuse treated wastewater?		
Choices	Frequency	Percentage
Yes	114	78.6%
No	31	21.4%

5.2.5.11 The Best Ways to Raise Environmental Awareness in Rafah Governorate

The results show the best way to raise environmental awareness in Rafah about (35.9%) suggest make field visits, (24.8%) suggest by lectures, (12.4%) suggest distribution of printed, (9%) by activating neighborhood committees, others (17.9%) suggest all previous ways.

Table (5.45): Best ways to raise environmental awareness

What is the best way to raise environmental awareness in your area?		
Choices	Frequency	Percentage
Distribution of printed	18	12.4%
Field visits	52	35.9%
Lectures	36	24.8%
Activating neighborhood committees	13	9.0%
All of this	26	17.9%

5.2.6 Impact of Social and Cultural Aspects on Acceptance

5.2.6.1 The Relation between Education Level and accepting the use of Treated Wastewater for Irrigation

Table (5.46) shows the relation between education levels and accept use treated wastewater for irrigation, the Chi-square test analysis: assumption two variables are independent.

P-value =0.00095 < α= 0.05, so reject the null hypothesis (variables are related), this mean there is a close relationship between the educational level in Rafah governorate and accept the use of treated wastewater in irrigation crops, provided they are safe and healthy.

Deek et al. (2010) supported that there are differences of statistical significance, but for the benefit of learners, that is, persons with more education have more receptive to the use of treated wastewater.

Table (5.46): The relation between education level and accepting the use of treated wastewater for irrigation

Accepting the use of treated wastewater for irrigation		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Education Level	Uneducated	12	17.1%	11	10.7%	23
	Elementary School	14	12.0%	7	25.0%	21
	Preparatory School	28	17.1%	3	39.3%	31
	Secondary	29	24.8%	4	14.3%	33
	Diploma	26	22.2%	2	7.1%	28
	University graduate and over	8	6.8%	1	3.6%	9

5.2.6.2 The Relation between Monthly Income and accepting the use of Treated Wastewater for Irrigation

Family income is one of the indicators of social well-being can be from work in the agricultural sector, government sector, and other free businesses. Table (5.47) shows the relation between monthly incomes and accept use treated wastewater for irrigation, the Chi-square test analysis: assumption two variables are independent.

P-value =0.77632 > α= 0.05, so cannot reject the null hypothesis (variables are independent), this mean there is non-relationship between the monthly income for

families in Rafah governorate and accept the use of treated wastewater in irrigation crops, even if they are safe and healthy.

Deek et al. (2010) concluded that there are no statistically significant differences of monthly income of families and the extent to which people accept the use of treated wastewater. This supports the earlier conclusion of the current study hypothesis.

Table (5.47): The relation between monthly income and accept use treated wastewater for irrigation

Accepting the use of treated wastewater for irrigation		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Total monthly income of the family	Less than 600 NIS	16	13.7%	3	10.7%	19
	From 600 to less than 1,000 NIS	36	29.9%	9	35.7%	45
	1,000 to less than 2,000 NIS	45	44.4%	13	21.4%	58
	Over 2,000 NIS	20	12.0%	3	32.1%	23

5.2.6.3 The Relation between Preferred term to Describe Treated Wastewater and accepting the use of Treated Wastewater for Irrigation

Table (5.48) shows the relation between preferred term to describe treated wastewater and accept use treated wastewater for irrigation, the Chi-square test analysis: assumption two variables are independent.

P-value $= 0.00023 < \alpha = 0.05$,so reject the null hypothesis (variables are related), this mean there is a close relationship between the preferred term to describe treated wastewater and accepting the use treated wastewater for irrigation in Rafah governorate.

Therefore, the quality of the term that should be put in the publications and articles about this should be taken into account subject, taking into account the social, psychological, economic and environmental factors of the population of the region affects population decisions about accepting wastewater management projects (Hartly and Troy, 2006).

Table (5.48): The relation between preferred term to describe treated wastewater and accepting the use treated wastewater for irrigation

Accepting the use of treated wastewater for irrigation		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Preferred term to describe treated wastewater	Reused water	41	35.0%	3	10.7%	44
	Treated wastewater	8	6.8%	9	32.1%	17
	Reclaimed or purified water	68	58.1%	16	57.1%	84

5.2.6.4 The Relation between accepting the use of Treated Wastewater for Irrigation and trust that the Municipality treat Wastewater well

Table (5.49) shows the relation between accepting the use of treated wastewater for irrigation and trust that the municipality treat wastewater well, the Chi-square test analysis: assumption two variables are independent.

P-value =0.02075 < α= 0.05 ,so reject the null hypothesis (variables are related), this mean there is a close relationship between opinion best field about using of treated wastewater for irrigation in Rafah governorate and the trust the municipality will treat wastewater as well.

Table (5.49): The relation between accepting the use of treated wastewater for irrigation and trust that the municipality treat wastewater well

Accepting the use of treated wastewater for irrigation		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Trust people that the municipality treat wastewater well	Confident	74	63.20%	11	39.30%	85
	Not sure	43	36.80%	17	60.70%	60

5.2.6.5 The Relation between the area of Owing Land and accepting the use of Treated Wastewater for Irrigation

Table (5.50) shows the relation between the area of owning land and accepting the use of treated wastewater for irrigation, the Chi-square test analysis: assumption two variables are independent.

P-value =0.00383< α= 0.05, so reject the null hypothesis (variables are related), this mean there is a close relationship between the area of owned land and accepting the use of treated wastewater for irrigation.

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Table (5.50): The relation between the area of owing land and accepting the use of treated wastewater for irrigation

Accepting the use of treated wastewater for irrigation		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Area of land (dunums)	Less than 5 dunums	57	48.7%	6	21.4%	63
	From 5 less than 8 dunums	35	29.9%	7	25.0%	42
	From 8 to less than 12 dunums	21	17.9%	8	28.6%	29
	More than 12 dunums	4	3.4%	7	25.0%	11

5.2.6.6 The Relation between Participating in Environmental Awareness Programs to Reuse Treated Wastewater and Educational Level

Through awareness campaigns that will demonstrate the potential of using treated wastewater and its areas of use, as well as understanding the quality and characteristics of treated water and considering it as a source of water conservation.

Table (5.51) shows the relation between participating in environmental awareness programs to reuse treated wastewater and educational level, the Chi-square test analysis: assumption two variables are independent.

P-value $= 0.0015 < \alpha = 0.05$, so reject the null hypothesis (variables are related), this mean there is a close relationship between participate in environmental awareness programs to reuse treated wastewater and educational level.

Table (5.51): The relation between participating in environmental awareness programs to reuse treated wastewater and educational level

Participate in environmental awareness programs to reuse treated wastewater		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Educational level	Uneducated	18	15.8%	5	16.1%	23
	Elementary School	15	13.2%	6	19.4%	21
	Preparatory School	17	14.9%	14	45.2%	31
	Secondary	28	24.6%	5	16.1%	33
	Diploma	27	23.7%	1	3.2%	28
	University graduate and over	9	7.9%	0	0.0%	9

Chapter Six

Conclusions and

Recommendations

Chapter Six

Conclusions and Recommendations

This chapter presents the conclusion derived from the results of the study and the main recommendation for relevant institution and researchers.

6.1 Conclusions

The reuse of RWW is a major priority to meet the increase water demands of the agricultural sector due to water scarcity in Gaza Strip.

The achieved research findings of this study gave a significant data. The research outcome records can assess the related institutions and other future researchers' in better understanding of the performance and effectiveness of reuse wastewater in irrigation from RWWTP.

1. Current wastewater effluent from RWWTP is unsuitable for irrigation due to the higher concentration of BOD, COD, TKN, Na, Mg, Cl, SAR, TSS, FC, and TDS these concentrations are above the permissible limit according to the Palestinian standards, but parameters (NH_4, NO_3, P, Ca, pH, Cd, Pb, and Cu) still in allowable range.

2. The use of treated wastewater for irrigation of all social, cultural, and environmental aspect is feasible, but from a technical standpoint, Rafah Wastewater Treatment Plant needs improvement to meet Palestinian Standards, however after installing a sand filter it will be technically possible.

3. Effluent treated wastewater quality of the RWWTP, it is concluded that the produced wastewater from RWWTP do not meet the low quality criteria Class D standards, concerning BOD and TSS.

4. The value of SAR for TWW of RWWTP was 9.73 meq/l, slightly exceed the maximum allowable value 9 meq/l, acceptable according to (FAO, 1992 & PS-742-2003) guidelines standards. Which the value of SAR should not exceed the permissible level of 10 to have Stable Soil, classified based on SAR as: Excellent (<10).

5. The Effluent quantities of Rafah treatment plants (12,000 m^3/day) meet the required quantities for agriculture irrigation (10,783 m^3/day), and when addition remaining population to connect at sewer system, RWWTP

production will reach 22,415 m³/day, it is therefore a valuable asset for Rafah governorate, which can be used in wide ranges.

6. The researcher found most of the farmers, about 80.7%, would accept using treated wastewater in irrigation. The highest yield was the most relevant reason for accepting the use of treated wastewater, because of increasing salinity level in the local agricultural wells, increasing fuel price, and maintenance cost.

7. The results showed a close relationship between education level and acceptance for use treated wastewater for irrigation, with compliy with Deek et al. (2010) study, that persons with more education have more receptive to the use of treated wastewater.

8. The results showed a close relationship between accepting the use of treated wastewater for irrigation and trust that the municipality treat wastewater well.

9. The results showed a close relationship between sources of water used in irrigation and accepting the use of treated wastewater for irrigation.

10. The researcher believes that these public awareness campaigns contribute to the sustainability of the treated wastewater projects and reuse of the treated wastewater for irrigation, and there is a close relationship between participating in environmental awareness programs to reuse treated wastewater and educational level.

11. The results showed a close relationship between the preferred term to describe treated wastewater and accepting the use treated wastewater for irrigation in Rafah governorate, the best preferred term is reclaimed or purified water and taken percentage 57.9%.

12. The results showed that there is a close relationship between the area of owning land and accepting the use of treated wastewater for irrigation.

13. The results showed that there is no close relationship between monthly incomes and accepting the use of treated wastewater for irrigation, or between opinion best field about using of treated wastewater and trust the municipality will treat wastewater as well.

6.2 Recommendations

Based on the achieved results of the study, the following points can be recommended in order to produce a suitable reuse system of treated wastewater in the Rafah governorate. The research recommendations are stated on the light of all the discussions above, as follows:

1. TWW need quality monitoring to ensure safe effect on public, and animal health.

2. Research should be done on from similar projects on a larger scale and for a long period of time.

3. The researcher recommends study the acceptance of the consumption of agricultural products irrigated with treated wastewater from a consumer point of view.

4. Further research studies are needed to explain TWW effect from agriculture ministry and the health ministry for more public health.

5. Workshops and presentations should be held to the public about the benefits and economic value of using treated wastewater for irrigation to reduce fertilizers used.

6. The researcher recommends the importance of using treated wastewater in irrigation and excess quantities from agricultural needs to inject in the aquifer.

7. Researchers should study adding disinfection unit to kill or decrease pathogens that found in effluent wastewater from RWWTP to meet the stander parameters and protect farmers to decrease pollutions by chlorination.

8. This study to improve wastewater and reuse in irrigation, so we recommended to build more units in RWWTP especially as sand filters that all treatment units produce partially treated wastewater, which need to improvement use in agriculture, and reach the Palestinian standards for direct reuse of wastewater in agriculture.

9. More efforts are needed to improve the characteristics of treated wastewater from RWWTP, especially salinity parameters, BOD_5, TSS and fecal coliform, in order to expand the capability of reuse in agriculture.

10. Studies should be done on the economic benefits expected from similar projects on a larger scale.

11. The researcher recommends to prepare a study which is focusing on the study of the financial cost, the price of treated wastewater should be differentiated, because farmers will not use it to replace fresh water irrigation unless it is much cheaper.

12. The researcher believes that these public awareness campaigns contribute to the sustainability of the TWW projects for irrigation, by conducting training and public awareness programs targeting students at schools, householders, and farmers must be conducted to raise the knowlgment and culture.

13. Public awareness campaign must have the priority in the strategic plan for any reuse project.

14. Periodic monitoring systems of test quality parameters should be adopted to ensure successful, safe and long term reuse of wastewater for irrigation.

15. Built a legal organization of qualified personnel to be responsible for managing, operating and maintaining, all functions related to deliver the wastewater reuse service in order to assure sustainability of the agricultural reuse water system.

16. The researcher recommends that the appropriate price for the treated wastewater should not exceed 0.4 NIS.

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Appendices

APPENDIX 1: Arabic version of questionnaire

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استبيان
دراسة الجدوى من إعادة استخدام المياه الناتجة عن محطة المعالجة برفح

الرجاء وضع علامة (X) أمام الخيار الذي يتناسب مع اجابتك

1- المستوى التعليمي :

☐ أمي   ☐ إبتدائي   ☐ إعدادي   ☐ ثانوي   ☐ دبلوم متوسط

☐ جامعي

2- الفئة العمرية:

☐ أقل من 18 عام   ☐ من 18 إلى أقل من 30 عام   ☐ من 30 الى أقل من 45 عام

☐ 45 عام فأكثر

3- عدد أفراد الأسرة العاملين في الزراعة:

☐ أقل من 3   ☐ من 3 إلى أقل من 5   ☐ من 5 الى أقل من 10

☐ أكثر من 10

4- الدخل الشهري الإجمالي للأسرة :

☐ أقل من 600 شيقل   ☐ من 600 إلى أقل من 1000 شيقل   ☐ من 1000 الى أقل من 2000شيقل

☐ أكثر من 2000 شيقل

5- هل تعتبر الأرض المصدر الوحيد لدخل أسرتك:

☐ نعم   ☐ لا   ☐ أحياناً

6- عدد سنوات الخبرة في مجال الزراعة:

☐ أقل من سنتين   ☐ من 2 إلى أقل من 5 سنوات   ☐ من 5 إلى 10 سنوات

☐ أكثر من 10 سنوات

</div>

7- علاقة المزارع بالمزرعة:

☐ مالك المزرعة ☐ شريك ☐ مستأجر ☐ عامل

8- مساحة الأرض المملوكة (دونم):

☐ أقل من 5 دونم ☐ من 5 إلى أقل من 8 دونم ☐ من 8 الى أقل من 12 دونم

☐ أكثر من 12 دونم

9- نوع ملكية الأرض:

☐ أراضي حكومية ☐ أراضي طابو ☐ أراضي أوقاف ☐ أراضي سبع

☐ أراضي حبال (أراضي غير مسجلة) ☐ لا اعرف

الجزء الثاني: تأثير نظام تصريف مياه الصرف الصحى المستخدم على البيئة المحيطة

الرجاء وضع علامة (X) أمام الخيار الذي يتناسب مع اجابتك

1- هل تؤيد وجود نظام لتجميع مياه الصرف الصحي في أحياء محافظة رفح؟

☐ مؤيد ☐ غير مؤيد ☐ لا أعرف

2- كيف يتم التخلص من مياه الصرف الصحي في منطقتك؟

☐ حفر امتصاصية ☐ حفرة مصممة (غيرمنفذة) ☐ شبكة الصرف الصحي

☐ جريان في قنوات مفتوحة

3- هل تعتقد أن التخلص من مياه الصرف الصحي بطريقة عشوائية يؤثر على الصحة العامة والأراضي الزراعية؟

☐ نعم ☐ لا ☐ لا أعرف

4- أي من المشكلات يعاني منها ساكنو منطقتك بسبب التخلص من مياه الصرف الصحي العادمة؟

☐ بعوض ☐ رائحة كريهة ☐ طفح الصرف الصحي في الشوارع ☐ جميع ما ذكر

☐ لا شئ مما ذكر

الجزء الثالث : أنماط الزراعة واستخدامات الأراضي

الرجاء وضع علامة (X) أمام الخيار الذي يتناسب مع اجابتك

1- هل تقوم بزراعة الأرض؟

☐ نعم ☐ لا ☐ أحياناً

2- هل تعتمد على نظام الزراعة المروية؟

☐ نعم ☐ لا (انتقل لسؤال 6) ☐ أحياناً

3- ما هي طريقة ري المحاصيل التي تستخدمها؟

☐ الري بالخرطوم ☐ التنقيط ☐ رشاشات ☐ قنوات

☐ غير ذلك، حدد ....

4- ما هي مصدر مياه الري التي تستخدمها؟

☐ آبار زراعية ☐ مخزون مياه أمطار ☐ مياه بلدية

☐ مياه معالجة

5- كم تقدر كمية المياه التي تستخدمها أسبوعياً في ري المزروعات؟

☐ 1-10 كوب ☐ 11-20 كوب ☐ 21-30 كوب ☐ 31-40 كوب

☐ أكثر من 40 كوب

6- في حال كنت لا تستخدم الزراعة المروية فإن السبب يعود في ذلك إلى؟

☐ عدم وفرة المياه ☐ ارتفاع التكلفة ☐ لا ترغب في استخدامها

☐ غير ذلك ، حدد ....

7- أعاني من شح في توفر كميات المياه في فصل؟

☐ الصيف ☐ الشتاء ☐ طيلة أيام السنة

☐ في بعض أيام السنة

8ـ ما هو نوعية الأسمدة التي تستخدمها في الزراعة؟

☐ الأسمدة الكيماوية   ☐ الأسمدة العضوية (مخلفات الحيوانات والطيور)

☐ كلاهما   ☐ لا أستخدمها

الجزء الرابع : قياس رغبات العاملين في القطاع الزراعي في استخدام مياه الصرف الصحي المعالجة

الرجاء وضع علامة (X) أمام الخيار الذي يتناسب مع اجابتك

1ـ ما هي نوعية المحاصيل التي تزرعها؟

☐ محاصيل حقلية   ☐ أشجار مثمرة   ☐ أشجار غير مثمرة

☐ خضروات   ☐ حمضيات   ☐ زيتون

☐ محاصيل متنوعة

2ـ هل تثق بأن البلدية سوف تعالج مياه الصرف الصحي بشكل جيد؟

☐ واثق   ☐ غير متأكد

3ـ ما هو المصطلح الذي تفضل استخدامه لوصف مياه الصرف الصحي المعالجة؟

☐ المياه المعاد استخدامها   ☐ مياه الصرف الصحي المعالجة

☐ المياه المستصلحة أو المنقاة

4ـ إذا تم معالجة مياه الصرف الصحي بضمان صلاحية استخدامها في ري المزروعات، فهل انت مع استخدامها في ري الأرض المزروعة

☐ نعم (انتقل لسؤال 6)   ☐ لا

5ـ في حال عدم الرغبة في استخدام مياه الصرف الصحي المعالجة في ري المزروعات فإنه يعود إلى أسباب؟

☐ نفسية   ☐ دينية   ☐ ثقافية

☐ المخاطر الصحية   ☐ بيئية   ☐ جميع ما ذكر

6ـ هل تعتقد أن توافر كميات من مياه الصرف الصحي المعالجة سيشجع أصحاب الأراضي على زيادة مساحة الأرض المزروعة؟

☐ نعم   ☐ لا

7ـ هل يمكنك استخدام المخلفات الصلبة (الحمأة) الناتجة عن مياه الصرف الصحي المعالجة كسماد للتربة إذا كانت آمنة وغير ممرضة؟

☐ نعم   ☐ لا   ☐ محايد

8ـ الأفضلية برأيك في إعادة استخدام مياه الصرف الصحي المعالجة في مجال؟

☐ الزراعة   ☐ البناء   ☐ إطفاء الحرائق   ☐ الصناعة (كالتبريد)

☐ استعمالات أخرى

9ـ أي من الأسباب تؤثر على تقبلك لفكرة استخدام مياه الصرف الصحي المعالجة لأغراض الري؟

☐ توفّر المياه   ☐ سعر المياه المعالجة مقارنة بالمياه العذبة

☐ تقبل الناس لشراء المحاصيل المروية بالمياه المعالجة   ☐ التخوف من مخاطر صحية

☐ جميع ما ذكر   ☐ ليس مما ذكر

10ـ موقفك المجمل بشأن إعادة استخدام مياه الصرف الصحي المعالجة في الاستخدامات الأخرى غير الزراعية؟

☐ موافق   ☐ غير موافق   ☐ محايد

11ـ في حال موافقتك على استخدام مياه الصرف الصحي المعالجة في ري المزروعات فإنك تفضل استخدامها في ري؟

☐ المحاصيل العلفية (علف للحيوانات كالبرسيم)   ☐ الأشجار المثمرة

☐ الخضروات   ☐ الزيتون   ☐ محاصيل لا تؤكل (كالورود والقطن)

12ـ أوافق على استخدام مياه الصرف الصحي المعالجة في الزراعة لاعتقادي؟

☐ مصدر جديد للمياه   ☐ سيزداد الانتاج بسبب المغذيات في مياه الصرف الصحي

☐ المياه المعالجة متوفرة طوال الوقت   ☐ جميع ما ذكر

13- إذا علمت أن المنتجات الزراعية التي اشتريتها كانت مروية بمياه الصرف الصحي المعالجة فإنني؟

☐ أرفض تناولها مطلقاً لانها تضر بالصحة   ☐ أرفض تناولها مطلقاً لأنها نجسة من الناحية الدينية

☐ أتناولها لأنها لا تضر بالصحة ولا تتعارض مع التعاليم الدينية

☐ أتناولها فقط إذا لم يوجد بديل من المحصول مروي بمياه عادية

الجزء الخامس : قياس الوعي البيئي

الرجاء وضع علامة (X) أمام الخيار الذي يتناسب مع اجابتك

1- هل سبق وأن زرت محطة معالجة الصرف الصحي الموجودة في منطقتك؟

☐ نعم   ☐ لا

2- ايجابيات وجود محطة لمعالجة مياه الصرف الصحي العادمة في منطقتك؟

☐ إعادة استخدام نواتجها في الزراعة   ☐ التقليل من انتشار الأمراض

☐ تحسين المستوى الصحي   ☐ جميع ما ذكر

3- ما هي سلبيات وجود محطة معالجة في منطقتك؟

☐ عدم الثقة بجودة مياه الصرف الصحي المتجة   ☐ عبئ مالي على البلدية عند الصيانة

☐ الرائحة الكريهة   ☐ طفح مياه الصرف الصحي

4- هل ترى أنه من الضروري الفحص المستمر لمياه الصرف الصحي المعالجة في المختبرات للتأكد من صلاحيتها في ري المزروعات؟

☐ نعم   ☐ لا أعرف   ☐ أحياناً

5- هل تعرف بأن معظم المحاصيل الزراعية التي تأتي من إسرائيل مروية بمياه الصرف الصحي المعالجة؟

☐ نعم (انتقل لسؤال 7)   ☐ لا

6ـ إذا كانت الإجابة السابقة لا، وعرفت الآن بأنها تروى من مياه الصرف الصحي المعالجة، هل ستقوم بالتوقف عن استهلاك هذه المنتجات؟

☐ نعم   ☐ لا

7ـ هل ترى بأنك بحاجة إلى شرح وتفسير يثبت عدم الضرر من استخدام مياه الصرف الصحي المعالجة في ري المزروعات؟

☐ نعم   ☐ لا

8ـ هل شاركت ببرامج توعية حول إعادة استخدام مياه الصرف الصحي المعالجة في ري المزروعات؟

☐ نعم   ☐ لا

9ـ ما هو السعر المناسب في رأيك لكوب مياه الصرف الصحي المعالجة لاستخدامها في الزراعة؟

☐ صفر   ☐ 20 أغورة   ☐ 40 أغورة   ☐ 50 أغورة

☐ غير ذلك، حدد ....

10ـ هل أنت على استعداد للمشاركة في برامج التوعية البيئية لإعادة استخدام مياه الصرف الصحي المعالجة؟

☐ نعم   ☐ لا

11ـ ما هي الطريقة الأفضل في رفع مستوى الوعي البيئي في منطقتك؟

☐ توزيع نشرات مطبوعة   ☐ زيارات ميدانية   ☐ محاضرات

☐ تفعيل لجان الأحياء   ☐ جميع ما ذكر

APPENDIX 2: English version of questionnaire

General information :Part I

It aims to collect information on the quality and nature of the farms, including the level of age, education, years of practical experience in agriculture, and the area of agricultural tenure and ownership.
Please tick (X) in front of the option that matches your answer

1. Educational level:

☐ Uneducated ☐ Elementary school

☐ Preparatory school

☐ Secondary ☐ Diploma

☐ University graduate

2. Age group:

☐ Less than 18 years ☐ From 18 to less than 30 years

☐ From 30 to less than 45 years ☐ 45 years and over

3. Number of family members working in agriculture:

☐ Less than 3 ☐ From 3 to less than 5 ☐ From 5 to less than 10

☐ 10 and over

4. Total monthly income of the family?

☐ Less than 600 NIS ☐ From 600 to less than 1,000 NIS

☐ 1,000 to less than 2,000 NIS ☐ Over 2,000 NIS

5. Is land the only source of income for your family?

☐ Yes ☐ No

☐ Sometimes

6. Years of experience in agriculture:

☐ Less than 2 years   ☐ From 2 to 5 years   ☐ From 5 to 10 years

☐ Over 10 years

7. Farmer's relationship with the farm:

☐ Farm owner   ☐ Partner   ☐ Tenant

☐ Worker

8. Area of land (dunums):

☐ Less than 5 dunums   ☐ From 5 less than 8 dunums

☐ From 8 to less than 12 dunums   ☐ More than 12 dunums

9. Type of land ownership:

☐ Government land   ☐ TABO land   ☐ Land of endowments

☐ Sheva land   ☐ hebal land (unregisted land)

☐ I do not know

Part II :Effect of wastewater disposal system on the surrounding environment

It aims to identify the methods of disposal of the current wastewater and measuring its effect in cases of the use of random disposal methods and the consequences thereof, such as the diseases that cause them.

Please tick (X) in front of the option that matches your answer

1. Do you support the existence of a sewage collection system in Rafah?

☐ Supporter   ☐ Not supportive

☐ I do not know

2. How do people disposal from wastewater in your area?

☐ Cesspit tanks   ☐Septic tanks (non-infiltration)

☐ Wastewater network   ☐ Runoff in open channels

3. Do you think that the random disposal of wastewater affects on public health and agricultural land?

☐ Yes   ☐ No   ☐ I do not know

4. Which of the problems do residents of your area suffer from wastewater disposal?

☐ Mosquitoes   ☐ Bad smell   ☐ Street sewage rash

☐ All of this   ☐ Nothing of this

Part III: Patterns of Agriculture and land Use

It aims to measure land use and determining the water needs of agricultural activities using irrigated agriculture as well as identifying obstacles facing farmers in irrigation.

Please tick (X) in front of the option that matches your answer

1. Do you cultivate the land?

☐ Yes   ☐ No   ☐ Sometimes

2 - Do you rely on the system of irrigated agriculture?

☐ Yes   ☐ No (move to question 6)

☐ Sometimes

3. What is the irrigation method for the crops you use?

☐ Irrigation with hose   ☐ Drip   ☐ Sprayers

☐ Channels   ☐ Other, select....................

4. What water sources do you use?

☐ Agricultural wells   ☐ Rainwater storage   ☐ Municipal water

☐ Treated wastewater

5. How much water do you use to irrigate crops?

☐ 1-10 m^3 ☐ 10- 20 m^3 ☐ 20- 30 m^3

☐ 30- 40 m^3 ☐ Over 40 m^3

6. If you do not use irrigated agriculture, why?
   (Note / If you are using irrigated agriculture, go to Question 7)

☐ Lack of water   ☐ High cost   ☐ Do not want to use it

☐ Other, select ....

7. suffer from a lack of availability of water quantities in a season?

☐ Summer   ☐ Winter

☐ All days of the year   ☐ Some days of the year

8. What is the type of fertilizers used in agriculture?

☐ Chemical fertilizers   ☐ Organic fertilizers (animal and bird residues)

☐ Both   ☐ Do not use them

Part IV: Measurement of the wishes of workers in the agricultural sector in the use of treated wastewater

To study the economic, cultural and social aspects of the possibility of accepting or rejecting the reuse of wastewater treated wastewater in agriculture.

Please tick (X) in front of the option that matches your answer

1. What types of crops do you cultivate?

☐ Field crops   ☐ Fruitful trees   ☐ Un-fruitless trees

☐ Vegetables   ☐ Citrus   ☐ Olive   ☐ various crops

2. Do you trust that the municipality will treat wastewater well?

☐ Confident   ☐ Not sure

3. What term do you prefer to describe treated wastewater?

☐ Reused wastewater   ☐ Treated wastewater

☐ Reclaimed or purified water

4. If the wastewater is treated with a guarantee of its use in irrigating the plants, are you using it to irrigate the cultivated land?

☐ Yes (move to question 6)   ☐ NO

5. In case of un-willingness to use treated water for irrigating crops, it is for reasons?

☐ Psychological   ☐ Religio   ☐ Cultural

☐ Health risks   ☐ Environmental   ☐ All of this

6. Do you think that the availability of treated wastewater will encourage landowners

  to increase space cultivated land?

☐ Yes   ☐ NO

7. Can you use sludge from treated wastewater as soil fertilizer if it is safe and non-pathogenic?

☐ Yes   ☐ NO   ☐ Neutral

8. What is your opinion best field about using of treated wastewater?

☐ Agriculture   ☐ Construction

☐ Fire extinguishing   ☐ Industry (ex: Cooling)   ☐ Other uses

9. Which of the causes affects your idea of using treated wastewater for irrigation purposes?

☐ Water availability

☐ The price of treated wastewater compared to fresh water

☐ People accept to buy irrigated crops with treated wastewater

☐ Fear of health risks   ☐ All of the this

☐ It is not mentioned

10. Your overall position on the reuse of treated wastewater?

☐ Agree   ☐ Disagree   ☐ Neutral

11. If you agree to use treated wastewater for irrigation, you prefer to use it in irrigation?

☐ Fodder crops (ex:animal feed such as clover)   ☐ Fruitful trees

☐ Vegetables   ☐ Olive   ☐ Crops not eaten (ex: roses and cotton)

12. You agree to use treated wastewater in agriculture for your belief?

☐ A new sources of water

☐ Production will increase due to nutrients in wastewater

☐ Production will increase due to nutrients in wastewater

☐ Wastewater treated is available all the time   ☐ All of this

13. If you know that the agricultural products were bought irrigated with treated wastewater, you will?

☐ I refuse to eat it never because it is harmful to health

☐ I refuse to eat them never because they are impurity in terms of religion

☐ I refuse to eat them never because they are impurity in terms of religion

☐ I eat this because they do not harm health and do not conflict with religious teachings

☐ I only eat it if there is no alternative crop irrigated by normal water

Part V: Measuring Environmental Awareness

Aims to assess the environmental impact and environmental value of farmers.

Please tick (X) in front of the option that matches your answer

1. Have you ever visited your sewage treatment plant in your area?

☐ Yes ☐ NO

2. The advantages of exist a wastewater treatment plant in your area?

☐ Reuse treated wastewater in agricultur ☐ Minimize the spread of diseases

☐ Improve health level ☐ All of the this

3. What are the disadvantages of having a treatment plant in your area?

☐ Lack of confidence in the quality of water produced

☐ A financial burden on the municipality during maintenance

☐ Bad smells ☐ Wastewater overflow

4. Do you think it is necessary to continuously inspect the treated wastewater in laboratories to ensure that it is suitable for irrigating crops?

☐ Yes ☐ I do not know ☐ Sometimes

**5. Do you know that most of the agricultural crops that come from Israel are irrigated
with treated wastewater?**

☐ Yes (move to question 7) ☐ NO

6. If the previous answer is not, and you know now that it is being irrigated from treated wastewater, will you stop consuming these products?

☐ Yes ☐ NO

7. Do you think that you need explanation that proves non harmless from the use of treated wastewater to irrigate crops?

☐ Yes ☐ NO

8. Have you participated in awareness programs on wastewater reuse in irrigation of crops?

☐ Yes ☐ NO

9. What do you think is the right price for cubic meter from treated wastewater in agricultural use?

☐ Zero ☐ 20 agura ☐ 40 agura ☐ 50 agura

☐ Other, select.....................

10. Are you willing to participate in environmental awareness programs to reuse treated wastewater?

☐ Yes ☐ NO

11. What is the best way to raise environmental awareness in your area?

☐ Distribution of printed ☐ Field visits

☐ Lectures ☐ Activating neighborhood committees

☐ All of this

APPENDIX 3: Wastewater effluent records months of RWWTP in year 2015.

Month	Previous meter Reading	Current meter Reading	Number day of month	Q (m3/d)	Status
1	8305555	8696575	31	13980	Rainy
2	8705820	9017975	28	11148	Spring
3	9029988	9360505	31	10662	Spring
4	9373366	9703645	30	11009	Spring
5	9711607	10071675	31	11615	Spring
6	10078411	10427163	30	11625	Summer
7	10445885	10804275	31	11561	Summer
8	10820993	11097827	31	11673	Summer
9	11111939	11439460	30	10917	Summer
10	11451150	11812988	31	11672	Rainy
11	1501757	1864713	30	12099	Rainy
12	1849955	2284877	31	14030	Rainy

APPENDIX 4: Result analysis for relationships (Chi-square tests)

1- Relation between education level and accepting the use of treated wastewater for irrigation

Accepting the use of treated wastewater for irrigation		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Education Level	Uneducated	12	17.1%	11	10.7%	23
	Elementary School	14	12.0%	7	25.0%	21
	Preparatory School	28	17.1%	3	39.3%	31
	Secondary	29	24.8%	4	14.3%	33
	Diploma	26	22.2%	2	7.1%	28
	University graduate and over	8	6.8%	1	3.6%	9

Chi-square tests for education level related to accepting the use of treated wastewater

for irrigation

Assumption: H_0 - two variables are independent	
Significance Level 95%, α	0.05
Number of rows	6
Number of columns	2
Degrees of Freedom, df =	5
Chi-square	20.6428
p-value	0.00095

p =0.00095< α= 0.05, reject the null hypothesis (Variables are Related).

2- Relation between monthly income and accepting the use of treated wastewater for irrigation

Accepting the use of treated wastewater for irrigation		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Total monthly income of the family	Less than 600 NIS	16	13.7%	3	10.7%	19
	From 600 to less than 1,000 NIS	36	29.9%	9	35.7%	45
	1,000 to less than 2,000 NIS	45	44.4%	13	21.4%	58
	Over 2,000 NIS	20	12.0%	3	32.1%	23

Chi-square tests for monthly income related to accepting the use of treated

wastewater for irrigation

Assumption: H_0 - two variables are independent	
Significance Level 95%, α	0.05
Number of rows	8
Number of columns	2
Degrees of Freedom, df =	7
Chi-square	4.0300
p-value	**0.77632**

p =0.77632> α= 0.05, cannot reject the null hypothesis (variables are independent)

3- Relation between preferred term to describe treated wastewater and accepting the use of treated wastewater for irrigation

Accepting the use of treated wastewater for irrigation		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Preferred term to describe treated wastewater	Reused water	41	35.0%	3	10.7%	44
	Treated wastewater	8	6.8%	9	32.1%	17
	Reclaimed or purified water	68	58.1%	16	57.1%	84

Chi-square tests for preferred term to describe treated wastewater related to accepting the use of treated wastewater for irrigation

Assumption: H_0 - two variables are independent	
Significance Level 95%, α	0.05
Number of rows	3
Number of columns	2
Degrees of Freedom, df =	2
Chi-square	16.7505
p-value	0.00023

p =0.00023< α= 0.05, reject the null hypothesis (Variables are Related).

4- Relation between accepting the use of treated wastewater for irrigation and trust that the municipality treat wastewater well

Accepting the use of treated wastewater for irrigation		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Trust people that the municipality treat wastewater well	Confident	74	63.20%	11	39.30%	85
	Not sure	43	36.80%	17	60.70%	60

Chi-square tests for trust people that the municipality treat wastewater well related to accepting the use of treated wastewater for irrigation

Assumption: H_0 - two variables are independent	
Significance Level 95%, α	0.05
Number of rows	2
Number of columns	2
Degrees of Freedom, df =	1
Chi-square	5.3480
p-value	**0.02075**

p =0.02075< α= 0.05, reject the null hypothesis (Variables are Related).

5- Relation between area of owning land and accepting the use of treated wastewater for irrigation

Accepting the use of treated wastewater for irrigation		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Area of land (dunums)	Less than 5 dunums	57	48.7%	6	21.4%	63
	From 5 less than 8 dunums	35	29.9%	7	25.0%	42
	From 8 to less than 12 dunums	21	17.9%	8	28.6%	29
	More than 12 dunums	4	3.4%	7	25.0%	11

Chi-square tests for area of land owned related to accepting the use of treated wastewater for irrigation

Assumption: H_0 - two variables are independent	
Significance Level 95%, α	0.05
Number of rows	4
Number of columns	4
Degrees of Freedom, df =	9
Chi-square	24.3159
p-value	**0.00383**

p =0.00383< α= 0.05, reject the null hypothesis (variables are related)

6- Relation between participates in environmental awareness programs to reuse treated wastewater and educational level

Participate in environmental awareness programs to reuse treated wastewater		Yes		No		Total
		Freq.	Perc.	Freq.	Perc.	
Educational level	Uneducated	18	15.8%	5	16.1%	23
	Elementary School	15	13.2%	6	19.4%	21
	Preparatory School	17	14.9%	14	45.2%	31
	Secondary	28	24.6%	5	16.1%	33
	Diploma	27	23.7%	1	3.2%	28
	University graduate and over	9	7.9%	0	0.0%	9

Chi-square tests for educational level related to participate in environmental awareness programs to reuse treated wastewater

Assumption: H_0 - two variables are independent	
Significance Level 95%, α	0.05
Number of rows	6
Number of columns	2
Degrees of Freedom, df =	5
Chi-square	19.5705
p-value	**0.00150**

p =0.0015< α= 0.05, reject the null hypothesis (Variables are Related).