

Al Azhar University – Gaza
Deanship of Postgraduate Studies
Institute of Water and Environment
Master of Water and Environment Science



**Impacts of Using Treated Wastewater in Irrigated Agriculture
on Efficiency of Farming Resources and Activities in Almawasi,
Khan Younis, Gaza Strip, Palestine.**

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master
of Science in Water and Environment

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Waster
and Environment

By

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I, the undersigned hereby, declare that the thesis titled: _____

Impacts of using treated wastewater in irrigated agriculture on efficiency of farming resources and activities in alnwasi - Khan Yunis, Gaza Strip, Palestine.

Is my own research work and the work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has never been submitted elsewhere for any other degree qualifications nor for any academic titles, nor for any other academic or publishing institutions.

I, hereto, affirm that I will be completely responsible in academic and legal terms if this work proves the opposite.

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Date: *13.4.2016*

DEDICATIONS

To my Father Spirit, and to my sincere Mother, for her kindness,

To my father in law, Eng. Omar Abu Ghalioun, for his great support and encouragement,

To my great wife, my lovely daughters and My Beloved Son Mohammed,

To all of my Brothers and Sisters,

And, to all those who believes in the richness of learning.

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Abstract

The Gaza Strip suffers severe shortage in water supply and sanitation due to its location, confinement, semiarid coastal climate and high population, therefore the use of treated wastewater for irrigation is increasingly considered as an effective solution of water resources scarcity. Monitoring study was conducted from January 2011 to December 2012 to investigate the quality of treatment process and the impact of recovery scheme on the irrigation water characteristics. The study, additionally explore farmers perception towards the use of treated wastewater in irrigated agriculture and its impact on technical and economic performance of crop production in the study area. Furthermore the study tries to explore the determinants of farmer's acceptance to use treated wastewater in irrigated agriculture.

The experimental sites were in located Al-Mawasi- Khan Younis area in the southern part of Gaza Strip. The study integrates two components. The first component focuses on the technical investigations which aim mainly to assess the quality of treatment process through measuring the quality parameters of effluent. Additionally, the technical investigations measure the same parameters of recovery well to assess the quality of water provided to irrigate. The second component handles the socioeconomic analyses and is based on data collected from 51 farmers in the study area using structured questionnaire.

Results indicated that quality of treatment does not meet the National Standards as parameters of the effluent are of a lower quality compared to the Palestinian Standard of effluent. The BOD of effluent is 132.5 mg/l while it is 45-60 mg/l in the Palestinian standards. However, recovery scheme improves the treated wastewater to meet the National Standards e.g. BOD of the recovery wells was 48.3mg/l which comes within the national standard rate.

Socioeconomic analyses described the differences between farmers accepting the use of treated wastewater and those who do not in terms of wide ranging economic and social indicators. Further logit model analyses indicated that education and well type are major determinants of farmer's acceptance to use treated wastewater in irrigated agriculture. Further analyses indicated that farmers did not notice any impact on crops quality as a result of using treated wastewater for irrigation. Farmers also did not recognize any impact of using TWW in irrigation on marketing of their products nor on the prices.

الملخص

يعاني قطاع غزة من نقص حاد في امدادات المياه وذلك ناتج من الموقع الجغرافي والزيادة السكانية لذلك اصبح اعادة استخدام المياه العادمة المعالجة من المصادر البديلة لمياه الري ومن الحلول المستدامة والفعالة للتغلب على هذه المشكلة. أجريت هذه الدراسة في ال فترة الزمنية من شهر يناير ٢٠١١ الى شهر ديسمبر ٢٠١٢ للتحقق من جودة المياه العادمة المعالجة و مياه الآبار الاسترجاعية و مدى تأثيرها في عمليات الري، بالإضافة الى ان الدراسة ساهمت في معرفة مدى إدراك المزارعين لفكرة استخدام المياه العادمة المعالجة في الزراعة و مدى تأثيرها على انتاج المحاصيل الزراعية من الناحية اقتصادية. علاوة على ذلك، الدراسة بينت مدى تقبل المزارعين لاستخدام المياه العادمة المعالجة.

الدراسة أجريت في منطقة المواصي بخانيونس جنوب قطاع غزة، و تضمنت عنصرين رئيسيين . العنصر الاول يتم من خلاله التحقق من مدى جودة المياه العادمة المعالجة و مياه الآبار الاسترجاعية من خلال دراسة الخواص الفيزيائية و الكيميائية و البيولوجية. أما العنصر الثاني، يسلط الضوء على المظاهر الاجتماعية و الاقتصادية من خلال عمل استبيانات لـ ٥١ مزارع في منطقة الدراسة.

أشارت النتائج الى ان مواصفات المياه العادمة المعالجة المستخدمة في الري أقل جودة و أعلى من المعايير الفلسطينية و مثال على ذلك الاكسجين المستهلك بيولوجيا في المياه العادمة المعالجة ١٣٢.٥ ملجم لكل لتر، بينما الاكسجين المستهلك بيولوجيا حسب المعايير الفلسطينية م ن ٤٥ - ٦٠ ملجم لكل لتر، بينما أشارت النتائج أن جودة المياه في الآبار الاسترجاعية ضمن المعايير الفلسطينية حيث ان الاكسجين المستهلك بيولوجيا يقدر بـ ٤٨.٣ ملجم لكل لتر.

من الجانب الاخر، أشارت نتائج دراسة المظاهر الاجتماعية و الاقتصادية الى ان المستوى التعليمي للمزارعين و انواع الآبار الزراعية و عدم ملاحظة اي تأثير في جودة المحاصيل او تغيير في اسعار المحاصيل الزراعية بالاسواق المحلية كان لها التأثير الكبير في فكرة تقبل المزارعين لاستخدام المياه العادمة المعالجة في الري.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Description
B^-	Boron
Ca^{2+}	Calcium
Cd^{2+}	Cadmium
Cl^-	Chloride
Cr^{2+}	Chromium
Cu^+	Copper
Fe^{2+}	Iron
H_2S	Hydrogen Sulfate
HCO_3	Bicarbonate
Hg^+	Mercury
K	potassium
Mg^{2+}	Magnesium
Mn^{2+}	Manganese
N	Nitrogen
Na^+	Sodium
Na_2CO_3	Sodium carbonate
NH_4^+	Ammonium
NH_4-N	Ammonium Nitrogen
Ni^{2+}	Nickel
NO_2^-	Nitrite
NO_3^-	Nitrate
P	Phosphorous
Pb^{2+}	Lead
pH	$-\log[H]^+$
SO_4^{2-}	Sulfate
Zn^{2+}	Zinc

ABBREVIATIONS

APHA	American Public Health Agency
BLWWTP	Beit Lahia Wastewater Treatment Plant
BOD ₅	Biochemical Oxygen Demand
Cfu	Colony Forming unit
CMWU	Coastal Municipalities Water Utility
COD	Chemical Oxygen Demand
ds/m	deci Siemens per meter
EC	Electrical Conductivity
EC _e	Soil Salinity
EPA	Environment Protection Agency
EQA	Environment Quality Authority
ESP	exchangeable sodium percentage
FAO	Food and Agriculture Organization
FC	Fecal Coliform
GS	Gaza Strip
GWWTTP	Gaza Wastewater Treatment Plant
ICARDA	International Center for Agriculture Research in Dry Areas
ICRC	International Red Cross Community
KYWWTP	Khan Younis Temporary Treatment Plant
M	Meter
m/s	Meters per Second for Speed
m ³	Cubic meter
m ³ /y	Cubic meter per year
MCM	Million Cubic Meters
meq/l	Milliequivalent Per Liter
MF	Membrane Filtration
mg/l	Milligram Per Liter
MOA	Ministry of Agriculture
MPN	most popular number
MSL	Mean sea level
NTU	Nephelometric Turbidity Unit

PS	Palestinian Standard
PWA	Palestinian Water Authority
RWWTP	Rafah Wastewater Treatment Plant
SAR	Sodium Absorption ratio
SAT	Soil Aquifer Treatment
TC	Total Coliform
TDS	Total Dissolved Solids
tons/ha	ton per hectare
TSS	Total Suspended Solids
UNDP	United Nations Developing Program
UNEP	United Nations Environment Program
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
WWR	Wastewater Reuse
$\mu\text{s}/\text{cm}^{-1}$	micro Siemens per cm

CHAPTER 1

INTRODUCTION

1.1 Background

Water is a vital resource but it is severely limited in most countries of the Mediterranean region such as Palestine. Many countries are struggling to balance water use among municipal, industrial, agricultural, and recreational uses. The population increase has not only increased the fresh water demand but also increased the volume of wastewater generated. (Qian, 2005). The importance of wastewater reuse is increasing as a result of growing water demands in semi-arid areas all over the world. (Ezio Ranieri, 2011). This is generally the situation in the Mediterranean region. A number of Mediterranean countries regularly experience severe water supply and demand imbalances (Coppola et al 2004). Since wastewater is considered as a non-ordinary source of water, its usage in the agriculture demands a unique management, which in addition to its appropriate utilization, has to have no threat to the environment, plants, soils and surface and subsurface water resources (Najafi, 2001). The Gaza Strip is classified as a semi-arid region and suffers from water scarcity. The renewable amount of water that replenishes the groundwater system is much less than the demanded amount, and this resulted in deterioration of the groundwater system in both quantitative and qualitative aspects (Hamdan 2006). The annual average rainfall varies from 400 to 200mm at the north to south respectively. Total abstraction of groundwater in Gaza Governorates exceed $155\text{Mm}^3 \text{ year}^{-1}$ (Hamdan et al 2007). Around two third of ground water pumped through more than 4000 wells used for agriculture propose. $55\text{-}60 \text{ Mm}^3$ annual deficit of water balance, due to increasing of the gap between water demand and water supply, as a result of rapid population growth in this small area (Nassar, 2009).

There are large quantities of wastewater produced by the municipal sewerage systems and the treated effluents are disposed to the sea or flooded without good treatment or control to the surrounding areas and underground aquifer.

In the Gaza Strip, there is assumed that there are four Wastewater Treatments Plants:

1. Beit Lahia Wastewater Treatment Plant (BLWWTP).
2. Gaza Wastewater Treatment Plant (GWWTP).
3. Rafah Wastewater Treatment Plant (RWWTP).
4. Khan Younis Temporary Treatment Plant (KYWWTP).

1.2 Agriculture Water Consumption

All over the world, the agricultural sector is the dominant user of water by humans, accounting for more than two-thirds of withdrawals. In developing countries agricultural use may reach 90% of total water use, with the remainder being used for domestic and industrial purposes (FAO, 92). During the last fifty years there was a rapid increase in agricultural water consumption and it is expected to continue. In Gaza Strip, the total water demand for agriculture and domestic use accounts for 80 and 47 Mm³ year, respectively. The total water demand for the agricultural sector represent around 60% of total water demand. Water consumption for vegetable crops accounts for 47.7 Mm³ year which constitutes around 58% of total water demand for the agricultural sector. Citrus fruit, olives, almonds and other fruits consume around 33 MCM a year, which represent 40% of total water demand for agriculture sector (Al-Najar, 2007).

1.3 Problem Description

The globally, over 70% of freshwater consumption is devoted to agricultural activities (FAO 2008). Water resources in Gaza Strip are very limited. Over exploitation of the aquifer diminished seriously the quantity and quality of ground water badly needed for human consumption as well as for agriculture; one of the main sources of income in the Gaza Strip. The reuse of treated wastewater could be an important alternative to solve the water deficit crisis in Gaza Strip (EQA 2005).

Reuse of treated wastewater in irrigation is considered a priority in the Gaza Strip due to a number of factors including the depletion of groundwater resources and the fact that reuse would increase the availability of freshwater resources for domestic and industrial use. A safe and feasible wastewater reuse scheme is a prerequisite to progressively inaugurate large scale projects due to the social, religious and economical aspects (EQA 2011).

Assuming that 80% of the water used for domestic usage comes back as wastewater, Gaza produces about 25 MCM/year. About 40% of the wastewater that is generated in Gaza is currently discharged into the sea; a minor part infiltrates into the soil and contaminates the groundwater, (Shomar, 2004). Even the use of treated wastewater to meet increasing agriculture water demand was identified as one of the main objectives of the Palestinian water sector, neither enough data nor comprehensive analysis to address the effects of using wastewater for irrigation in GS is being carried out..

1.4 Study Justifications

The study aims at investigating the quality of irrigation water and if it meets the accepted National Standards through assessing quality parameters of both effluent and recovery wells. On the other hand, the study focuses on the farmer's perception towards the use of treated wastewater and its impact on crops technical and economic performance. Additionally, to investigate the factors affecting farmers acceptance to use treated wastewater

1.5 Objectives

Main objective:

To assess potentialities and quality of using treated wastewater from KYWWTP in irrigated agriculture.

Specific objectives:

- To assess the characteristics treated wastewater used for irrigation coming from effluent and recovery wells.
- Explore farmer's perception towards the use of treated wastewater for irrigation and its impact on crops technical and economic performance.
- Identify the determinants of farmer's acceptance to use treated wastewater.

1.6 Study structure

This study contains 5 chapters. The first chapter introduces the problem , outlines objectives and study justification . The second chapter presents the guidelines concerning wastewater reuse, the quality of wastewater and its potential impacts. The analyses of wastewater sample collection and socioeconomic questioner are exciting in the research area are presented in the third chapter. The fourth chapter includes the results of physical, chemical and biological quality of wastewater; in addition, explore farmers' perception, acceptance of using treated wastewater. Finally, the fifth chapter presents conclusion and recommendations.

CHAPTER 2

STUDY AREA

2.1 Study Area

2.1.1 Location and Topography of Gaza Strip

The Gaza strip is narrow coastal strip along the Mediterranean Sea, in the southern part of Palestine at coordinates (31°25' N 34°20'E). The total area of Gaza strip is about 365 km². It has a 51km border with Israel and an 11km with Egypt .the Gaza strip as shown in figure 2.1 include five governorates: Northern, Gaza, Middle, Khan Younis and Rafah. Gaza is located on the coast of the Mediterranean Sea, north of the Sinai Peninsula and southwest of Jerusalem, on a road that links Egypt with central Israel. Gaza Strip forms part of the coastal foreshore plain bordering the Hebron Mountains in the north-east, the Northern Negev desert in the south-east, and the Northern Sinai desert in the south. It is situated in the shadow of the Nile Delta and Northern Sinai. The curve in the coastal starting from El Arish towards north of Gaza. The topography of the coastal plain is determined by the exposure of Kurkar ridges. The age of these ridges increases from the coastline eastwards. In the north of the Gaza Strip there are four ridges: the coastal ridge (20m MSL), the Gaza ridge (up to 50m MSL), the El Muntar ridge (80m MSL), and the Beit Hanoun ridge (90m MSL). The ridges are separated by deep depression (20- 40m MSL) with alluvial deposits. There is evidence that there are at least three to four younger Kurkar ridges on the continental shelf, parallel to the present coastal line and several kilometers offshore. Kurkar ridges of calcareous sandstone appear all along the coast positioned in a south-west-northerly direction parallel to the coast. The influence of these Kurkar ridges on sedimentation and erosion processes is however limited to local disruption of waves and currents.

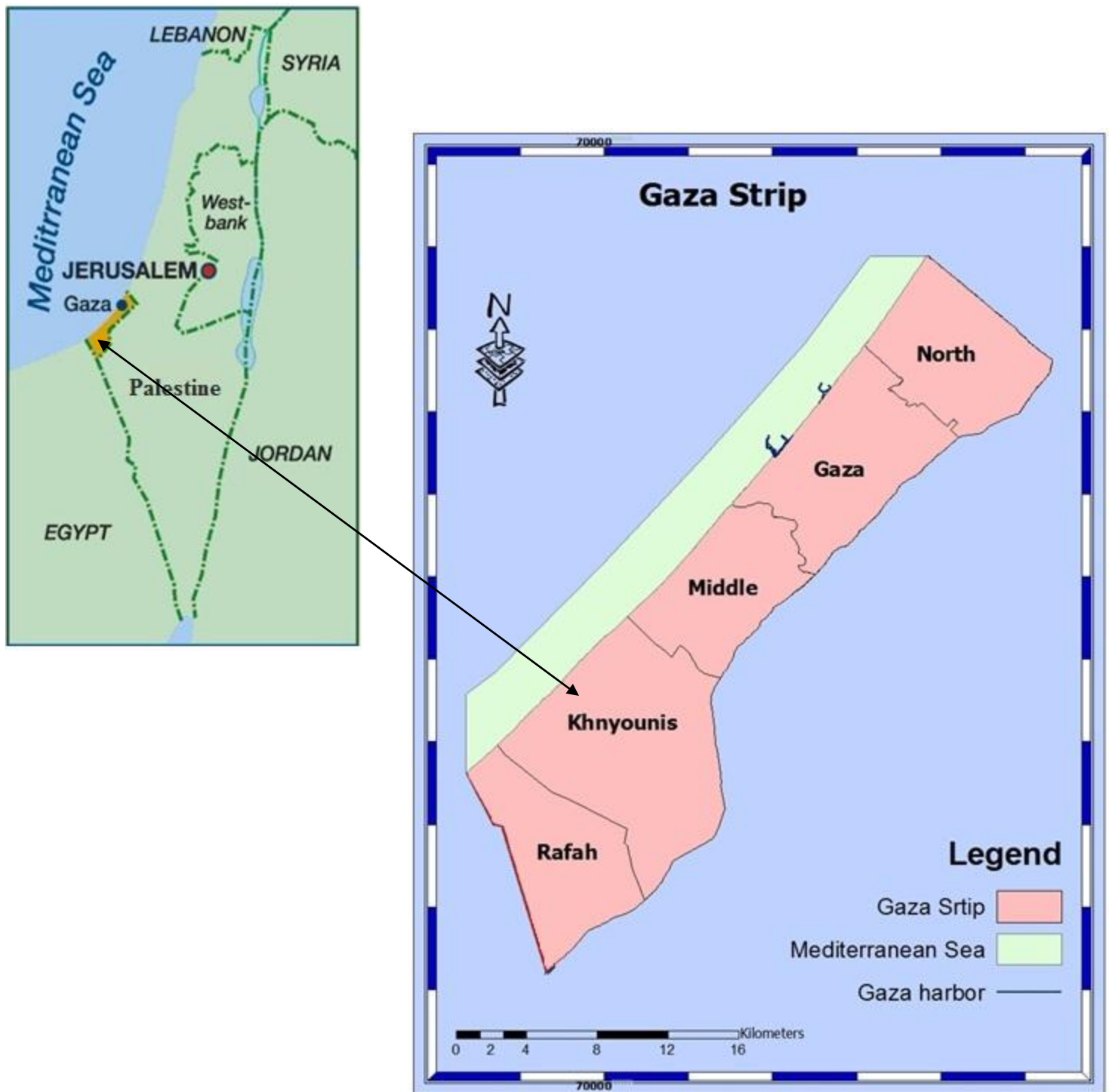


Figure 2.1: Map of the Gaza Strip (prepared by researcher, 2015)

2.1.2 Climate

The Gaza Strip is located in the transitional zone between the arid desert climate of the Sinai Peninsula and the semi humid Mediterranean climate along the coast. The following is climatological summary in the project area for the period.

- **Temperature:** the average daily mean temperature in the Gaza Strip ranges between 25.8⁰C in summer to 13.4⁰C in winter. The hottest month is August with an average temperature of 25 to 28 ⁰C and the coldest month is January with average temperature of 12 to 14 ⁰C.
- **Humidity:** the relative humidity fluctuates between 60% and 85%.
- **Wind:** in summer, sea breeze blow all day and land breeze blows at night. Wind speed reaches its maximum value at noon period and decrease during night. During the winter, most of the wind blow from the Southwest and the average wind speed is 4.2m/s. In summer, strong winds blow regularly at certain hours, and the daily average wind speed is 3.9m/s and come from the Northwest direction. Storms have been observed in winter with maximum hourly wind speed of 18m/s.
- **Rainfall:** the winter is the rainy season, which stretches from October up to March. Rainfall is the main source of recharge for groundwater. The rate of rainfall is varying in the Gaza Strip and ranges between 160mm/year in the south to about 400mm/year in the north, while the long term average rainfall rate in all over the Gaza Strip is about 317mm/year (CMWU, 2011). For the last ten years, between 2001 and 2011, the average annual rainfall of Gaza trip ranged between 220mm/year to 520mm/year (MOA, 2011).

2.1.3 Environmental situation

The Gaza Strip has been a theatre of conflict for decades. Each of these conflicts has left its mark, and over time, a significant environmental footprint has developed in the Gaza Strip (UNEP, 2009). Suffering from extreme environmental problems, the Gaza strip needs an urgent recovery and rehabilitation programs. Overpopulation has created adverse living conditions, influencing directly the quality of health and social well being of the population. In some situations, human and animal life is directly threatened and requires an immediate response. In others, adverse developments such as the unsuitability use of scarce resources

like land, water and semi natural landscape may inhibit economic and social development of the area in the medium term. Wastewater, land degradation, solid waste, noise pollution and drinking water quality and quantity is the main environmental problems which adversely affect the people of the Gaza strip.

2.1.4 Water Recourses

Groundwater is considered as the main source of fresh water and is of primary importance to the Palestinian in the Gaza Strip (Al-Agha, 1995). Moreover, the Palestinian Water Authority (PWA), purchase a big quantity of water from the Israeli water company Mekorot (PWA, Water supply report, 2012). However, surface water is represented with some water from valleys. It has been reported that the valleys may carry substantial amounts of water for relatively short time during the rainy season. In particular, the Wadi Gaza may transport a large amount of water. The floods may not occur every year and especially recently the floods of the Wadi Gaza have decreased as a result of the construction of dams and reservoirs on the upstream Israeli side (Abu Amr, 2006). Groundwater is recharged from several sources including rainwater, return from irrigation, sewage infiltration and seawater intrusion (PEPA, 1994). Pumped for people of the Gaza strip, groundwater is mainly from municipal wells which is basically use as the main source of drinking water source, while some people have open their own wells in their homes. On the other hand, there are many wells used for agricultural purposes.

2.1.5 Al-Mawasi- Khan Younis Pilot Project Study Area

Khan Younis governorate is located in the southern part of Gaza Strip with total population of 220,000 capita (PCBU, 2007). Khan Younis is bounded by the Rafah and Middle governorates from south and north respectively and by the green line and the Mediterranean Sea from east and west respectively. Khan Younis city is the major urban area in this governorate.

2.1.6 Target Area

Al-Mawasi area is located in the south-west part of the Gaza Strip along the Gaza sea shore. The area extends over 14Km with an average width of 1km, starting south of Deir Al Balah to south of Rafah. The area is about 11000 dunums forming 3% of the Gaza Strip area. Al-

Mawasi area is considered one of the most important areas from an environmental point of view due to the agro-biodiversity that exists in the area in addition to the high sensitivity of the groundwater aquifers to pollution. The water resources for domestic use are from groundwater wells, especially in the Al-Mawasi area, where 85% of people use groundwater as their main water resource. This indicates the importance and suitability of activities rehabilitating the groundwater wells. It is feared therefore that the future waste water discharge from the basins of Al Mawasi in to the sea will cause serious deterioration in the quality of the marine life in this area. The target area which located west of the Temporary wastewater treatment in Al-Mawasi area is about 110 dunums cultivated by Jawaffa, Palm, olive and citrus.

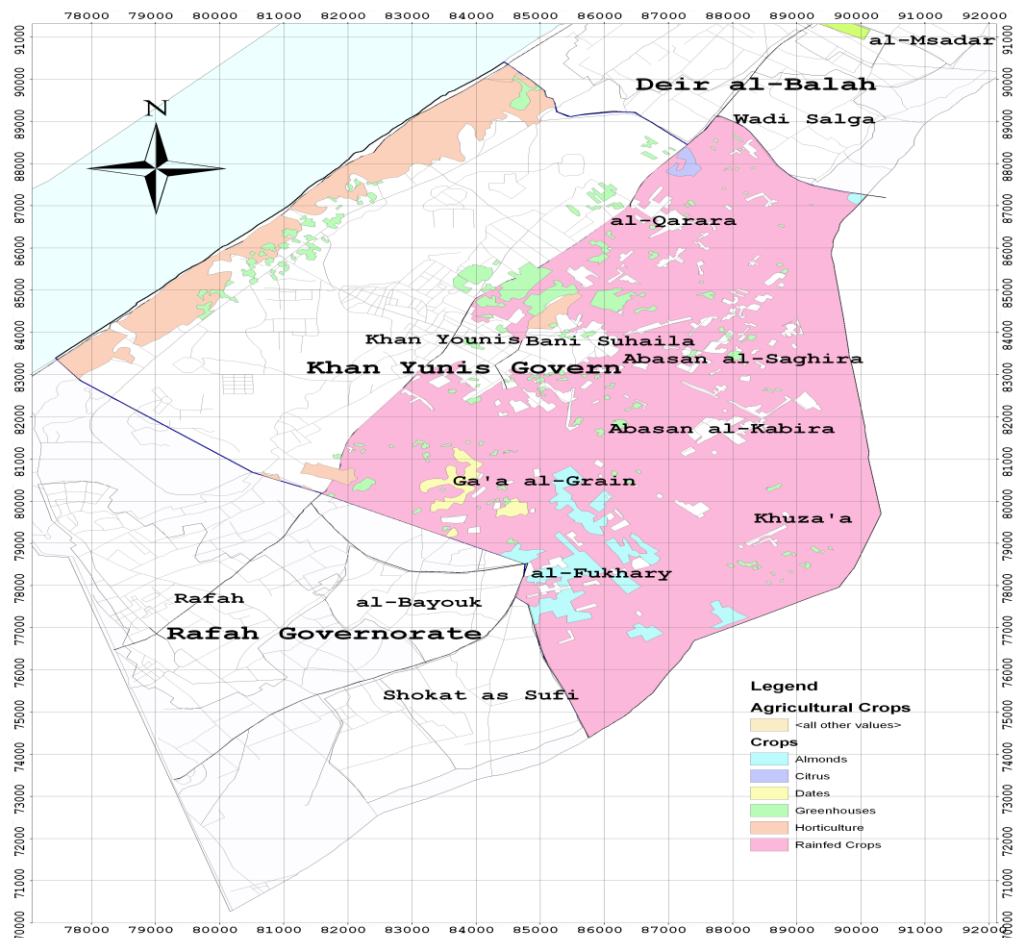


Figure 2.2: Khan Yonis Governorate Map (PWA, 2011)

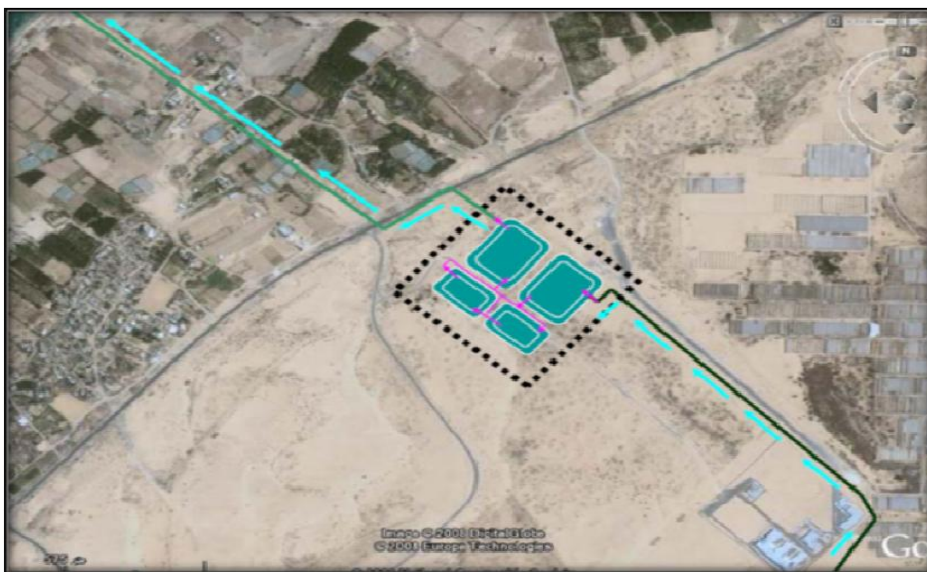


Figure 2.3: General layout for Almawasi

2.1.7 Wastewater system in khan Younis

The sewerage network in this city covers about 30 %, where as the rest of the city use septic pools to discharge their wastewater. Delay in the construction of Khan Younis wastewater treatment plant due to the present political situation resulted in conveying the collected wastewater to existing storm water infiltration ponds to the west of Al Amal refugee's. The Coastal Municipalities Water Utility (CMWU) with a fund of International Red Cross Community (ICRC) constructed temporary partially wastewater treatment plant with anaerobic, aerobic, and settling ponds. The plant was constructed in 2007 as a temporarily solution. The current flow rate is about 7000 m³/day, and it is currently discharging to the sea. In Khan Younis Governorate, wastewater disposal is the main environmental issue that has created unsanitary conditions, groundwater contamination, odor and mosquito problems affect people health. A sewage water pipe line constructed to convey the waste water collected in those basins directly in to the sea. Numerous complaints have been recorded by citizens who live in Al Mawasi area claiming that such basins cause serious hazards to the environment and the public health, such as wide spread offensive odors, harmful pests and wide spread of disease transmitting insects like mosquitoes. Increased loads of nitrates in wastewater may increase the risk of groundwater contamination. With a fund of the Catalan government, the JCP in close cooperation with Palestinian Water Authority (PWA) and Coastal Municipalities Water Utility (CMWU), launched a small pilot project started with 60 dunums in 2008,

expanded to 90 dunums in 2010 and reached its peak to 110 dunums in 2011 cultivated with Jawaffa and Palm trees. The BOD resulted from the recovery wells reaches 20-25mg/l.

2.1.8 SAT System in Almawasi, Khan Younis

Soil Aquifer treatment is an infiltration (or injection) of the sewage effluent into the aquifer, and the natural movement of the effluent within the groundwater acts as a natural filter to treat wastewater, decreasing BOD, TSS, bacteriological presence and metal concentration. Since the soil and aquifer are used as natural treatment, such system is called Soil-Aquifer Treatment system or SAT system. Soil-aquifer treatment is, essentially, a low-cost, advanced wastewater treatment system. It also has an aesthetic advantage over conventionally treated sewage in that water recovered from a SAT system is not only clear and odor-free but it comes from a well, drain, or via natural drainage, rather than from a sewer treatment plant. Thus, the water has lost its connotation of sewage and the public see the water more as coming out of the ground (groundwater) more than as sewage effluent. This could be an important factor in the public acceptance of sewage reuse schemes.

While the renovated water from a SAT system is of much better quality than the sewage effluent going into the soil, it could be of lower quality than the native groundwater. Thus, SAT system should be designed and managed to avoid encroachment into the native groundwater and to use only a portion of the aquifer for renovation of wastewater. The distance between infiltration basins and wells or drains should be as large as possible (usually at least 50-100m) to give adequate SAT. If the groundwater is deep and/or the soils are relatively fine, flow distances through the aquifer can be reduced. The recovered groundwater by the recovery wells will be collected by a collector and then through a transmission pipe line will be pumped to the farmers for agricultural purposes. The collector and the transmission line will be of 6 inches steel pipe with distance of 800meters. (PWA, 2010)

2.1.9 Groundwater Recovery Wells

In order to minimize the impact of the infiltrated partially treated wastewater on the local groundwater resources, the infiltrated water recovered after it passes through soil aquifer treatment process. Almost the same quantity of the infiltrated water will be recovered. The recovered groundwater provided to nearby farms for agricultural usage. Two recovery wells



Figure 2.4: Drip irrigation pattern

constructed west of the KYWWTP with a capacity of 50m³/hr. The locations of these wells based on model simulation runs done by PWA with depth of 20m.

2.1.10 Irrigation system

The irrigation system involved in this project is a drip irrigation system as shown in figure (2.4). In drip irrigation; water is applied to each plant separately in small, frequent, precise quantities through dripper emitters. It is the most advanced irrigation method with the highest application efficiency. The water is delivered continuously in drops at the same point and moves into the soil and wets the root zone vertically by gravity and laterally by capillary action. The planted area is only partially wetted. Drip systems can be used on any slope and are well suited to permanent planting, such as landscaping. The equipment and installation costs for drip do not create spray drift problems.

Specific Benefits of Drip Irrigation

- Increased crop growth and yield achieved by optimizing the water, nutrients and air regimes in the root zone.
- High irrigation efficiency because of minimal drainage loss.
- Minimal contact between farm workers and wastewater

CHAPTER 3

LITERATURE REVIEW

3.1 Introduction

Whenever good quality water is scarce, water of “marginal quality” will have to be considered for using in agriculture. Municipal wastewater is marginal quality water and using of this for irrigation can be an important consideration when its disposal is being planned in arid and semi-arid regions (Angelakis, 2002). Wastewater is used extensively for irrigation in certain countries e.g. 67% of total effluent of Israel, 25% in India and 24% in South Africa is reused for irrigation through direct planning. Clearly, agricultural and landscape irrigation represents the most important area in which this valuable resource is used (Kamizoulis, 2007). Treated waste-water represents a stable and reliable source of irrigation water and often provides significant levels of required plant nutrients, such as potassium and phosphorous. It has been successful for irrigation of a wide array of crops, and increases in crop yields from 10-30% have been reported (Asano, 1998). In addition, the use of wastewater in agriculture is a form of nutrient and water recycling, and this often reduces downstream environmental impacts on water resources in addition to help communities to grow more food and conserve precious water and nutrient resources. (WHO, 2006) On the other side, wastewater reuse in agriculture

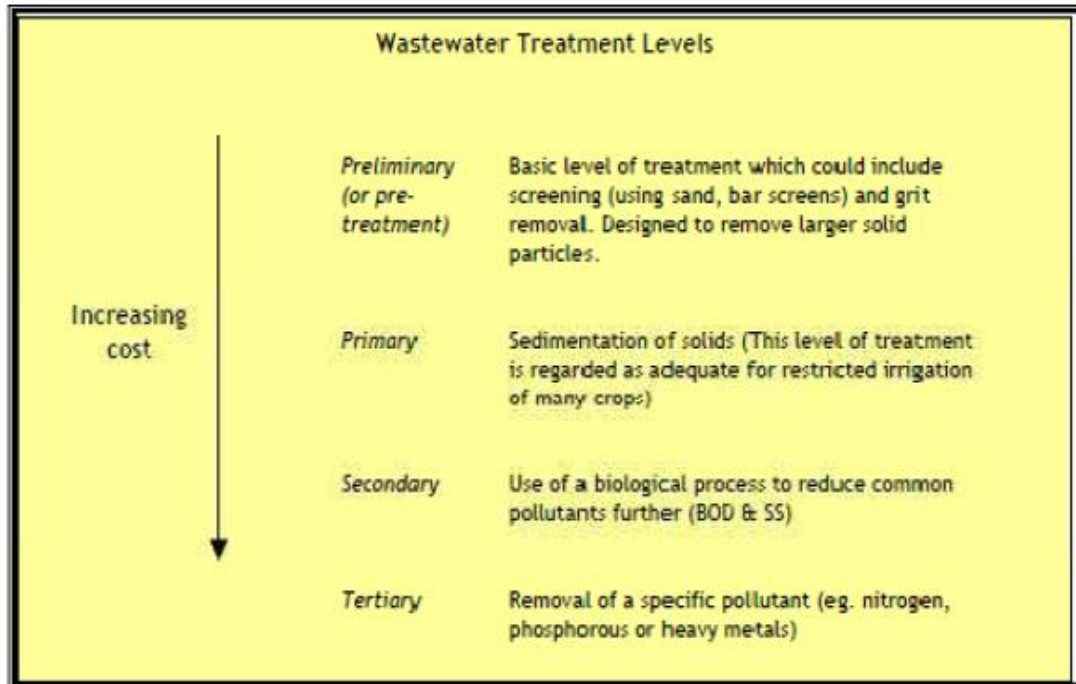


Figure 3.1: Typology of wastewater treatment processes

can pose some negative impacts caused by poor chemical balance and high wastewater contaminants that impacts accumulate over time. Soil will always take on the characteristics of the water with which it is irrigated. Evaluation should be carried out at regular intervals (minimum six months) to best manage the wastewater reuse projects (FAO, 92). It is agreed upon that any reuse project has to have impact assessment to account for its effects.

3.2 Wastewater treatment for reuse

Conventional wastewater treatment, typically, consists of a combination of physical, chemical, and biological processes and operations to remove solids, organic matter and, sometimes, nutrients from wastewater. General terms used to describe different degrees of treatment, in order of increasing treatment level, are preliminary, primary, secondary, and tertiary and/or advanced wastewater treatment (Figure 3.1). The minimum treatment required for restricted irrigation is secondary biological treatment and disinfection producing an effluent with BOD₅ and SS concentrations below 25 and 35 mg/l for 95% of the samples and a fecal coliform concentration below 200 FC/100 ml, as a median value and not exceeding 800 FC/100ml for 95% of the samples. (Andreadakis, 2001) The minimum treatment for unrestricted irrigation is secondary biological treatment, followed by tertiary treatment (normally coagulation, flocculation, sedimentation, and filtration) and disinfection, producing an effluent with BOD₅ and SS concentrations below 10mg /l for 80% of the samples and turbidities below 2NTU as an average value. Fecal coliform concentrations should be below 5 FC/100ml for 80% of the samples, below 15 FC/100ml for 95% of the samples, and not exceeding 100 FC/100ml in any sample.

3.3 The Status of Wastewater Reuse Practice in The Mediterranean Basin

3.3.1 Tunisia

RWW irrigation has had Government support since 1975, and since a severe drought in 1989, RWW use in irrigation has been a part of the Government's overall water resources management and environmental pollution control (World Bank, 2010). It is estimated that by 2020 about 20,000-30,000 ha, or about 7-10% of total irrigated area will be using RWW. The current rate of reuse is about 29%, reused for the cultivation of fruit trees, cereals, fodder crops and industrial crops as well as for golf courses and

green spaces. Wastewater is also reuse in recharges purposes and conservation of wetlands (Kamoun and Slimi, 2006).

3.3.2 Jordan

Jordan is one of the most water-deprived countries of the Middle East, and has some of the highest groundwater depletion rates. To meet growing water demands, more than 70 MCM of reclaimed wastewater, around 10 percent of the total national water supply, is used either directly or indirectly each year (World Bank, 2010). In 1993 the quantity of reused RWW reached 50 MCM, of which 48MCM for irrigation. In 2008 the amount of RWW reached 80 MCM .the total quantity of reused RWW is expected to grow from 80 MCM in 2008 to about 237 MCM in 2020.the reused RWW in Jordan reach one of the highest levels in the world .the importance of reused wastewater is an essential element of Jordan's water strategy .(MERAP, 2010).

3.3.3 Palestine

In spite the fact that there are very limited activities in the Palestinian territories for using reclaimed wastewater due to many reasons, there is a great potential for the reuse of this water resource to meet increasing agricultural water demand as a main objective of the Palestinian water sector. The total volume of treated urban wastewater for reuse is projected to be 12.1 MCM/yr for the main Palestinian cities by the year 2010. In comparison, the total water demand is projected to increase by 50 MCM/yr over the years 2005-2010. (MERAP, 2010). The reuse of treated wastewater could be an important alternative to solve the water deficit crisis in Gaza Strip. According to the Water Sector Strategic Planning Study, about 20,000 dunums are to be irrigated by RWW in the year 2010 and this will increase to about 60,000 dunums in the years 2020. The existing four WWTPs (Beit Lahia, Gaza, KhanYunis and Rafah) are heavily overloaded as a result of the rapid population growth. Currently, most of the effluent discharged from the four existing WWTPs in Gaza Strip is disposed into the Mediterranean Sea. Although the quality of the effluent from Gaza and even Beit Lahia WWTPs would nearly meet class C standards which are progressively match irrigating citrus, fodder crops and olives (EQA, 2005).

3.4 Potential wastewater reuse in Gaza strip

The three main treatment plants should be transferred to the eastern border of the Gaza strip and should work with treatment technology to produce treated effluent of a quality fit for fruit trees irrigation, (Al Najar, 2007).

The treatment plants are planned to be connected with a main carrier that would transfer the treated effluent to where it was needed as in Figure (3.2) a consequence of transferring the wastewater treatment plants to the eastern side by the year 2010, and the availability of treated wastewater is that, around 50 km² of fruit trees which are cultivated within and surrounding the residential areas could be transferred to the eastern side of the Gaza Strip if new policy to keep the production of fruits with least cost, and the reuse of treated effluent far away from the residential areas for health and safety reasons, is put into practice. This approach will reduce the costs of fruit production, and as a consequence will increase farm profits, considering the water resources crisis. (Al Najar, 2007)

3.5 Guidelines Concerning Wastewater Reuse

The guidelines provide vital information for collection, additional treatment and storage of treated effluent in such a manner that the use of ground water can be replaced, the aquifer can be enriched and the inflow of saline water into coastal aquifer can be reduced. There are many different guidelines aims at governing and controlling the impacts associated from WWR. All of it was initiated based on experimental data and results as follows:

- Australian Environmental Protection Agency (EPA 1991 and 2003): Guidelines for water reuse: Beside the reclaimed water quality guidelines, recommended monitoring and setback distances are given.
- Food and Agriculture Organization (FAO 1985, 1992, 1997 and 2000) (Quality criteria) determine the degree of suitability of a given effluent of irrigation.
- World Health Organization (WHO, 1989 and 2006): "Health Guidelines for the use of Wastewater in Agriculture and Aquaculture", they take into account the treatment process, irrigation system and the crops to be irrigated. This set of guidelines is controversial but has allowed a real development of wastewater reuse.
- American Environmental Protection Agency EPA, 2004 Guidelines for Water reuse.

3.6 Palestinian water policy

This policy principles form the important frame that guides the Palestinian Water Authority perspectives as the regulator of the water sector. The Policy principles were used as the base for different aspects of the water resources management including legal, regulatory, and administrative. The Palestinian Policy Principles

- Pursue Palestinian interests in connection with obtaining riparian rights to water resources shared with other countries;
- All sources of water are public property;
- Water has a unique value for human survival and health and all citizens have the right to water of good quality for personal consumption at costs they can afford;
- Water has social, environmental and economic values;
- Water supply must be based on sustainable development of all available and feasible water resources;
- Industrial and agricultural development and investment must be compatible and optimally integrated with the available resources and based on sustainable development;
- The development of Palestinian water resources must be coordinated at national level and carried out at the appropriate local level;
- The optimal development of water supply must be complemented by a consistent water demand management;
- Conservation and optimal utilization of water resources should be promoted and enhanced;
- Protection and pollution control of water resources should be ensured. The polluter pays principle will be applied in order to guarantee environmental protection;
- The government will cooperate with regional and extra-regional parties on programs and projects in order to promote the optimum utilization of water resources, to identify and develop new and additional supplies and to collect and share relevant information and data
- Public participation in the water sector should be ensured.

3.7 Palestinian Reuse standards

Recently, the Environment Quality Authority with coordination with Palestinian ministries and universities has established specific wastewater reuse regulations. The draft of Palestinian legislations for treated wastewater reuse is still under study in the Palestinian Standard Institute. The World Health Organization (WHO) recommendations and the neighbors countries standards were be used as main references for long time in Palestine.

The Draft of Palestinian standard envisages; sanitary, environmental and agrotechnical quality requirements.

a) Sanitary requirements centered upon the pathogens potentially present in wastewater, namely bacteria and intestinal nematodes (*Ascaris* and *Trichuris* species and hookworms). Where it's recommended less than 1 intestinal nematode per liter and 200 to 1000 fecal coliform per 100 ml of wastewater depending on the reuse conditions.

b) From the environmental viewpoint concentration of various heavy metals (particularly cadmium, copper, and zinc), salt, nutrients (N and P) and malodors have taken into consideration.

c) Agrotechnical requirements firstly include total salt and several anions (Cl , SO_4 , HCO_3), cations (Ca, Mg, Na) and boron concentrations which determine traditional irrigation water quality standards depending on the plant species, soil physical and chemical properties, climate and irrigation methods.

There are several other agrotechnical aspects in agricultural use of effluents like determination of land requirements, available effluent quantity, selection of crops and cropping pattern, estimation of irrigation requirements and finally wastewater storage needs and capacities.

Most of the reuse projects in Gaza Strip and West Bank are using treated wastewater for irrigation according to WHO and FAO guidelines. The WHO guidelines are strict in respect of the requirements to keep the number of eggs (*Ascaris* and Hookworms) in effluent below one egg per liter whether the effluent is used for restricted or unrestricted irrigation using surface and sprinkler irrigation. This is not applicable in case of restricted irrigation where exposure of workers and public does not occur.

On the other hand these guidelines are relaxed in the case of fecal coliform, as no standard is recommend for these pathogens in the case of restricted irrigation and 1000 or less per 100 ml in the case of unrestricted irrigation. This is based on the assumption that the treatment that results in effluent of having less than one egg per liter of intestinal will be practically safe in case of virus and bacteria.

In addition to the microbiological quality requirement of effluent used for irrigation attention also is given to quality parameters of importance in respect to ground water contamination and of soil structure and crop productivity. Nutrients content of the effluent (mainly nitrate), total dissolved solids, and sodium adsorption ratio and toxic elements (boron and heavy metals), are available at FAO guidelines.

Treated wastewater does not mean risk-free, different qualities of treated wastewater are exist; Table 3.1 presents the classification of the treated wastewater upon the main wastewater quality parameters, this table could be used to differentiate the uses of the treated wastewaters.

Table 3.1: Reclaimed wastewater classification (PWA)

Class		Water Quality Parameters		
		BOD ₅ mg/l	TSS mg/l	Fecal coliform MPN/100 ml.
Class A	High quality	20	30	200
Class B	Good quality	20	30	1000
Class C	Medium quality	40	50	1000
Class D	Low quality	60	90	1000

New regulations for WW reuse standards. In applying the provisions of this resolution, the following words and phrases have the following meanings unless the context indicates otherwise. In future see appendix 3.

3.8 Types of Wastewater Reuse

The collected wastewater must be treated to adjust its quality to any of the following end-uses (i) agriculture irrigation, (ii) artificial recharge, (iii) potable water supply, (iv) toilet flushing, and (v) industrial water supply. The two mostly common types of water irrigation based on water quality are:

- **Restricted irrigation:** use of low quality effluents in limited areas and for specific crops (wooden, fodder and cocked), restrictions are imposed based on the type of soil, the proximity of the irrigated area to a potable aquifer, irrigation method, crop harvesting technique, and fertilizer application rate. It is simple and low cost so farmers must be trained to handle the low-quality effluent.
- **Unrestricted irrigation:** use of high quality effluents, instead of freshwater, to irrigate any crop (include also vegetables eaten raw) on any type of soil, which means without limitations as contact and even accidental drinking do not pose health risks.

3.9 Evaluation of Water Quality

When using wastewater as a source of irrigation, factors such as contamination of plants and harvested product, farm workers, the environment, public health and salinity and toxicity hazards, need to be considered. There is considerable scope for reducing the undesirable effects of wastewater use in irrigation through selection of appropriate irrigation methods (FAO, 1992).

In recent guidelines four categories namely salinity, infiltration, toxicity and "miscellaneous problems" are used for evaluating conventional sources of irrigation water as in Table 3.2. The physical and chemical constituents in treated effluents need careful consideration in order to evaluate or detect possible short or long-term effects on soils and crops from salts, nutrients and trace elements (Ayers & Westcott, 1985). These general water quality classification guidelines help to identify potential crop production problems associated with the use of conventional water sources in addition to soil and environmental ones. Other criteria for evaluation of treated wastewater were developed by (Kathijotes, 2006) presented in Table (3.2). It was applied in the investigation of the risk of the treated sewage intended for irrigation in Cyprus during Stalinization risk assessment study. Results indicated that at most

time the quality of effluent in Cyprus is not suitable for irrigation use as it poses some risks for both soil and groundwater. This is interpreted as great care should be taken when using such effluents in order to minimize or eliminate possible contamination (Kathijotes, 2006).

3.10 Microbiological quality of wastewater

International guidelines for the microbiological quality of irrigation water used on a particular crop do not exist. The reason is the lack of direct epidemiological data to show any relationship between the quality of water actually applied at the field and disease transmission or infection (Kiziloglu, 2007).

According to EPA, 2003 the microbial criterion for reclaimed water based on the corresponding range of reuse is classified into four classes (A-D) where class A represents the tertiary treatment for unrestricted crops with high quality and class D represents the secondary treatment (minimum treatment level) for non food crops as in (Table 3.2) (EPA, 2003).

Table 3.2: Reclaimed water classes for biological and pathogen reduction and the corresponding range of reuse. (EPA, 2003)

Class	Water quality	Treatment level	Range of use include lower class uses
A	10 E-coli /100ml. 10/5 mg/l BOD/SS	Tertiary & pathogen reduction	Unrestricted ,Urban (Non potable) Industrial
B	100 E-coli /100ml. 20/30 mg/l BOD/SS	Secondary & Pathogen seduction	Agriculture , Industrial
C	1000 E-coli /100ml. 20/30 mg/l BOD/SS	Secondary & Pathogen reduction	Agriculture: human food crops/ cocked fodder crops
D	10000 E-coli /100ml. 0/30 mg/l BOD/SS	Secondary	Fodder crops , Wood crops ,flowers

3.11 Chemical quality of wastewater

Internationally, there is an increasing requirement for the inclusion of chemical parameters in guidelines or regulations concerning reuse of reclaimed water. This has been accelerated by the concern that some chemicals in low concentrations may show no direct toxic effects, but long term chronic effects or bioaccumulation in the environmental matrices. Environmental concerns are a further important factor, because several organisms show high sensitivity to some chemicals. Several irrigation regulations contain physicochemical or chemical parameters, but there is considerable variation among these guidelines, particularly regarding identifiable values, the limited quality standards or for defining techniques to reduce the risk; e.g. through good reuse practices. Modified versions of existing rules, based on data on epidemics and microbiological quality, and also on toxicity data, needs to be prepared in the near future, based on accumulated evidence. At the same time, risk data will be useful for reducing the costs for reclamation and reuse, not using expensive treatments where they are not needed and using them where the risk is higher. There is then a positive impact because a reduction in sanitary care derived from reduced possibility of infections, in work-time losses due to illnesses, and as a consequence an improvement of quality of life will appear (E. Huertas2008).

3.12 Potential Impacts of Wastewater Use in Agriculture

3.11.1 Public health impacts

As mentioned earlier, wastewater contains pathogenic microorganisms such as bacteria, viruses, and parasites, which have the potential to cause disease. In particular, human parasites such as protozoa and helminthes eggs are of special significance in this regard as they prove to be most difficult to remove by treatment processes and have been implicated in a number of infectious gastrointestinal diseases in both developed and developing countries. However, in evaluating health impacts it must be remembered that it is the actual risk that make people fall ill that must be quantified and not the presence of pathogens in water .

The use of untreated wastewater for irrigation, no doubt, poses a high risk to human health in all age groups. However, the degree of risk may vary among the various age groups. Untreated wastewater irrigation leads to relatively higher prevalence of hookworm (Feenstra

et al. 2000), and Ascariasis infections among children (Cifuentes et al. 2000; and Habbari et al. 2000).

In Eritrea, research on the health impacts of untreated wastewater revealed a *Guardia* infection rate of 45% of farmers using wastewater. Amongst consumers of the vegetables from these same farmers, infection rates were lower at 7% (UNEP, 2005).

Another problem is posed when heavy metals are present from, for example, industrial wastewater. Heavy metals can have a long-term impact on human health and soil quality. Cadmium (Cd) and mercury (Hg) are metals commonly found in untreated wastewater and have been linked to kidney disease (in the case of Cd) and brain and nervous system damage in the case of Hg (Amiri, 2008).

In Morocco, the use of row wastewater irrigation had revealed a transmission of geohelminthic infections among primary school, Ascariasis prevalence five times higher in wastewater impacted regions (Habbari et al 2000).

Erfani studied the microbial contamination of tomato fruit when irrigated using different water qualities including tap and treated wastewater, Fecal coliform in different treatments were measured and the results show that there is no significant difference between the different treatments. Additionally, with regard to health problems, these treatments generated minimum contact between the effluent and the workers, that is why microbial quality and health impact is the key of success of any reuse project and should be investigated (Erfani, 2001).

3.11.2 Environmental impacts

Wastewater irrigation poses several threats to the environment via contamination by nutrients, heavy metals, and salts. Increased loads of nitrates in wastewater may increase the risk of groundwater contamination (Stagnitti et al 1998). The risks can be markedly reduced, however, by appropriately matching plant production systems to effluent characteristics (Snow et al. 1999). High-yielding crops with large amounts of nitrogen in their biomass would be more effective than tree plantations at reducing nitrate leaching. However, the most important sustainability constraints are due to salinity and sodicity. Salinity is a pragmatic constraint for many horticultural reuse schemes. For example, at Australia's Werribee horticultural irrigation scheme, which commenced in 2005, salinity concerns lead to a

precautionary approach where the wastewater is mixed with river water before being (MWSRW 2004). Sodicity induces changes in the soil's physical properties, the most notable effect being the dispersion of soil aggregates. Dispersion, in combination with other processes, such as swelling and slacking, can affect plants through decreasing the permeability of water and air through the soil, water-logging and impeding root penetration. We are currently investigating sodicity management for the Australian viticultural industry, which is keen to exploit the benefits of wastewater irrigation. The research programme comprises two main parts: studies on the likely impact of waste-water irrigation on soil structural properties in vineyards (Hermon et al. 2004), and an assessment of the performance of a range of soil amendments and row management practices (Maher et al. 2004).

Another hidden impact is increased production of green house emissions. Water is "heavy" and transport costs can be high. For example, a large agricultural reuse project in Australia, was recently shelved primarily because the environmental externalities associated with pumping water uphill, i.e. greenhouse gas emissions, were too great (SEQRWTF 2003). This issue is not unique to wastewater, and other solutions such as desalination can be equally energy-hungry.

3.11.3 Impacts on soil

Impact from wastewater on agricultural soil, is mainly due to the presence of high nutrient contents (Nitrogen and Phosphorus), high total dissolved solids and other constituents such as heavy metals, which are added to the soil over time. Wastewater can also contain salts that may accumulate in the root zone with possible harmful impacts on soil health and crop yields. The leaching of these salts below the root zone may cause soil and groundwater pollution (Bond 1999). Prolonged use of saline and sodium rich wastewater is a potential hazard for soil as it may erode the soil structure and effect productivity. This may result in the land use becoming non sustainable in the long run. The problem of soil salinity and sodicity can be resolved by the application of natural or artificial soil amendments. However, soil reclamation measures are costly, adding to economic constraints resulting in losses to crop productivity. Moreover, it may not be possible to restore the soil to the original productivity level, by using these soil amendments. Hence, wastewater irrigation may have long-term economic impacts on the soil, which in turn may affect market prices and land values of saline and waterlogged

soils. Wastewater induced salinity may reduce crop productivity due to general growth suppression, at pre-early seedling stage, due to nutritional imbalance, and growth suppression due to toxic ions (Kijne et al. 1998). The net effect on growth may be a reduction in crop yields and potential loss of income to farmers. Wastewater irrigation may lead to transport of heavy metals to soils and may cause crop contamination affecting soil flora and fauna. Some of these heavy metals may bio-accumulate in the soil while others, e.g., Cd and Cu, may be redistributed by soil fauna such as earthworms (Kruse and Barrett 1985). Studies conducted in Mexico (Assadin et al. 1998), where wastewater mixed with river water has been used for crop irrigation for decades, indicate that polluted water irrigation may account for up to 31percent of soil surface metal accumulation and lead to heavy metal uptake by alfalfa. However, heavy metal concentrations in alfalfa pose no risk to animal or human health. In a critical assessment of USEPA heavy metal guidelines, McBride (1995), argues that heavy metals applied through sewage use can harm sensitive plants with possible loss of soil productivity.

3.11.3.1 Soil salinity

soil salinity has been defined and assessed in terms of laboratory measurements of the electrical conductivity of the extract of a saturated soil-paste sample (EC_e; this as well as all other symbols used in this report are summarized in the list of symbols): because electrical conductivity is an easily measured and practical index of the total concentration of ionized solutes in an aqueous sample.

As soils become more saline, plants become unable to draw as much water from the soil. This is because the plant roots contain varying concentrations of ions (salts) that create a natural flow of water from the soil into the plant roots.

As the level of salinity in the soil nears that of the roots, however, water becomes less and less likely to enter the root. In fact, when the soil salinity levels are high enough, the water in the roots is pulled back into the soil. The plants become unable to take in enough water to grow. Each plant species naturally contains varying levels of root salts. This is why some plants can continue to thrive when others have died.

If the salinity concentration in the soil is high enough, the plant will wilt and die, regardless of the amount of water applied. Figure (3.2) shows how the various salt concentrations affect the movement of water from the soil to plants.

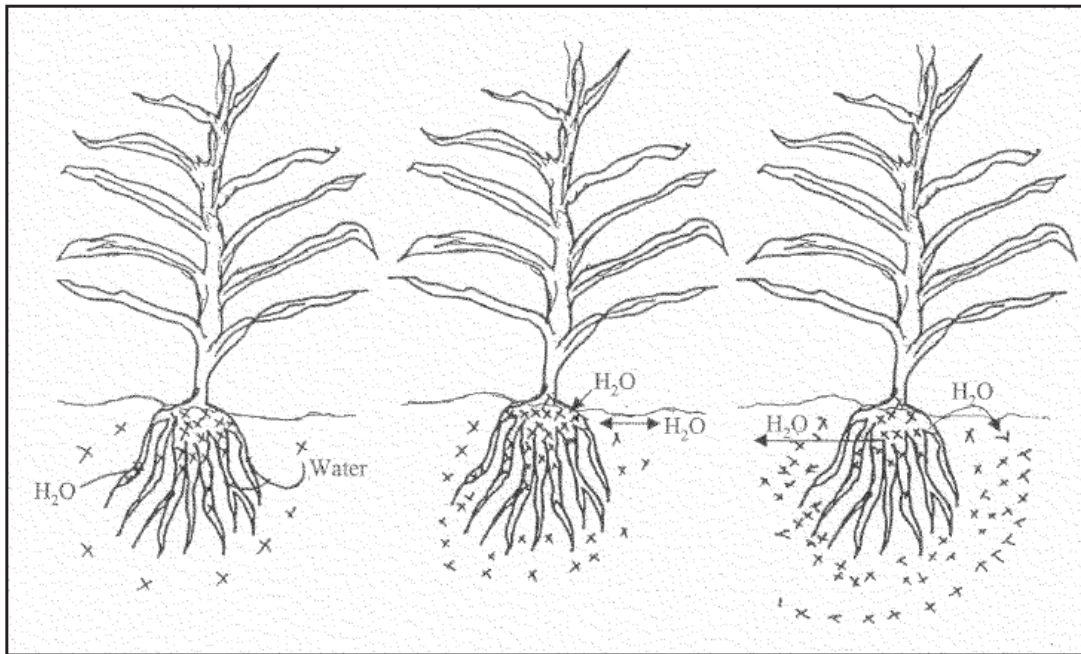


Figure 3.2: Increased salts in root zone can result in decreased water uptake by plant.

Soil salinity is strongly related to irrigated water salinity, Biswas et al. (2005) showed that during summer about 2 t of salt /ha would accumulate in the root zone (up to 60cm) if the irrigated water salinity is 0.8 ds/m. However, even at salinity of 0.3 dS/m, crop losses due to gradual salinity build up may be inevitable (Biswas et al. 2005).

Moreover salinity has direct relation with irrigation system, soil salinity was monitored in Sunraysia regions at depths of 0.3m, 0.6m and 0.9m following each irrigation or rainfall event, it was clearly noticed the salinity of soil water (ECe) peaked at 2.0 ds/m at 90 cm root zone depth under drip irrigated vineyard, but was rarely more than 1.5 ds/m in an undercover sprinkler citrus orchard. (Biswas, 2007).

Kathijotes, 2003 noticed that treated wastewater applied as irrigation to soils for the number of years irrigated, raises the EC to very high levels, compared to soils irrigated with normal fresh water. In samples irrigated with treated wastewater, the EC values range from 1.86

mS/cm at the surface layer to 11.77 mS/cm at the bottom zone. The soil irrigated with fresh water, shows minimum and maximum values ranging from 0.5 to 0.675 mS/cm.(Kathijotes, 2003).

Kathijotes, 2003 notice that the effects of the increase of salinity in the soils irrigated with treated wastewater as compare to the soils irrigated with fresh water is very clear in this investigation. There is a great increase of salt levels, EC and SAR in all layers of these soil profiles. If irrigation water with a high SAR is applied to a soil for years, the sodium in the water can displace the calcium and magnesium in the soil. This will causes increase of soil SAR, eventually decreasing the ability of the soil to form (Kathijotes, 2003).

The typical range of soil EC for forage crop production is from 0.7 to 3.0 dS/m. Soil with EC values greater than 3.0 dS/m may take a considerable effort to produce a crop and the feasibility of farming these soils with reclaimed wastewater should be carefully considered (Pool, 2004).

3.11.3.2 Soil alkalinity

The pH of the soil is a measure of acidity or alkalinity. It basically indicates how sour or sweet the soil is. The pH scale ranges from 0 to 14, with 7 being neutral. 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 (Hoffmann, 2010).

Alkaline soils are difficult to take into agricultural production. Rainwater stagnates on the soil easily and, in dry periods, irrigation is hardly possible. Agriculture is limited to crops tolerant to surface water logging (e.g. rice, grasses) and the productivity is low (R.J.Oosterbaan2003).

Soil alkalinity is associated with the presence of sodium carbonates (Na_2CO_3) in the soil, either as a result of natural mineralization of the soil particles or brought in by irrigation and/or floodwater.

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 and Siebe, 1996).

Plant absorption of ions from the soil to obtain essential nutrients could result in a nutrient deficiency with an increase in pH due to increased alkalinity, as some ions could be unavailable at a higher pH. Each plant has its own recommended soil pH value range. 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).

3.11.3.3 Soil sodicity

Sodicity is a term given to the amount of sodium held in a soil. Sodium is a cation (positive ion) that is held loosely on clay particles in soil. It is one of many types of cations that are bound to clay particles. Other types bound to clay particles include calcium, magnesium, potassium and hydrogen. When sodium makes up more than about 5% of all cations bound to clay particles, structural problems begin to occur, and the soil is said to be sodic. The amount of sodium as a proportion of all cations in a soil is the main measure of sodicity used, and is termed the exchangeable sodium percentage (ESP). This can be calculated from chemical soil tests.

High sodicity causes clay to swell excessively when wet. The clay particles move so far apart that they separate (disperse). This weakens the aggregates in the soil, causing structural collapse and closing-off of soil pores. For this reason water and air movement through sodic soils is severely restricted.

Permeability is either dependent on the sodium ion concentration relative to the concentration of calcium and magnesium ions.

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

Kathijotes, 2003 noticed that the quality of soil samples irrigated using fresh water in Cyprus for eleven years demonstrated higher values of SAR and therefore poses greater salinization

risks. This means that soil SAR values is mainly acquired from irrigated water sodium content (Kathijotes, 2003).

3.11.3.4 Soil toxicity

Agricultural soil contamination with heavy metals through the repeated use of untreated or poorly treated wastewater from industrial establishments and application of chemical fertilizers and pesticides is one of the most severe ecological problems. Wastewater from industries or other sources carries appreciable amounts of toxic heavy metals such as Cd, Cu, Zn, Cr, Ni, Pb, and Mn in surface soil which create a problem for safe rational utilization of agricultural soil (Syed Hafizur Rahman 2012).

Kiziloglu, 2007 stated that the major disadvantage of the wastewater irrigation is the accumulation of immobile heavy metals in soils as he noticed an increase in Fe, Mn, Zn and B of the soil 0-30cm and 30-60cm layers from 3.9 mg/Kg to 9.13 mg/Kg when irrigated with wastewater (Kiziloglu, 2007).

The results agree with that obtained by El-Arabi, 2006 as it was stated that the use of sewage effluent from 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 accumulation in soil and finally in crops. It has been demonstrated that the major source of contamination of comes from industrial effluent discharges which invariably find their usage into agricultural crops.

3.11.4 Impacts on ground water quality

Wastewater application has the potential to affect the quality of groundwater resources in the long run through excess nutrients and salts found in wastewater leaching below the plant root zone. However, the actual impact depends on a host of factors including depth of water table,

quality of groundwater, soil drainage, and scale of wastewater irrigation. For instance the quality of groundwater would determine the magnitude of the impact from leaching of nitrates. If the groundwater is brackish the leaching of nitrates would be of little concern as the water has no valuable use attached to it. The proximity of wastewater irrigation to sources of potable water supplies such as wells or tube wells will influence how we evaluate the severity of groundwater pollution effects (Hussain, et al, 2002).

Recharge from wastewater irrigation to the ground water was estimated of at least 1000 mm/year, or 50-70% of the water used for agriculture. On the other hand, percolation of excess nutrients, salts and pathogens through the soil may cause degradation of groundwater. However, the actual impact will depend upon a range of factors including scale of wastewater use, quality of groundwater, depth to water table, soil drainage, and soil characteristics (porous, sandy),(Christopher, 2001).

Any added water with chloride less than the existing groundwater will certainly improve the groundwater salinity by dilution. Groundwater chloride concentration will improve to the better and no needs to be checked through the model. Knowing that the chloride ion concentration is a conservative in which it flow on and mix with the groundwater and it is not affected by any degradation and/or adsorption processes (UNDP, 2009).

3.11.5 Impacts on crops

Wastewater is a rich source of plant food nutrients. Empirical studies show that the impact of wastewater irrigation on yield varies from crop to crop. If the crops are undersupplied with essential plant food nutrients, wastewater irrigation will act as a supplemental source of fertilizer thus increasing crop yields. Alternatively, if plant food nutrients delivered through wastewater irrigation result in over supply of nutrients, yields may negatively be affected. In the absence of any chemical fertilizer application, wastewater nutrients will act as a sole source of fertilizer, delivering savings in fertilizer cost. Thus, from an economic standpoint wastewater irrigation may have a three-fold effect on crops: (1) higher yields, (2) source of irrigation water, and (3) fertilizer value.

Tomato fruit size and weight increased with increasing the percentage of treated wastewater proportion. These results agreed with Maurer et al, 1995, who reported that citrus trees

receiving wastewater had significantly larger fruit (95mm) than those receiving canal water (90mm) (Erfani, 2001).

Najafi, 2002 found that after three times of harvesting tomatoes from various treatments, the mean yields were compared. Tap water irrigation had the least yield, while treated wastewater had the maximum yield which was about 52 tons/ha (18 tons/ha higher than the average yield of tap water) (Najafi, 2002).

Moreover it is reported that most crops give higher yields, when irrigated with wastewater than with fresh water and have less need for chemical fertilizers, resulting in net cost savings to farmers (Hussain et al., 2002).

3.11.6 Social Impacts

Social impacts are the concerns/doubts expressed by the public about wastewater irrigation. These concerns can be classified as follows:

General concerns such as nuisance, poor environmental quality, poor hygiene, odor, noise, higher probability of accidents, etc. Social concerns such as food safety, health and welfare, impaired quality of life, loss of property values, and sustainability of land use. Natural resource concerns such as pollution of vital water resources, loss of fish, wildlife, exotic species, etc. Public concerns about the perceived or real risks of wastewater irrigation may create business risks, which have to be addressed adequately to avoid exploitation by lobby groups. Business risks and potential liability can be covered by obtaining appropriate levels of insurance.

The premium for general risk assurance against wastewater irrigation is likely to be high at the beginning because, most developing countries, including Pakistan, do not have experience in agriculture sector insurance. Moreover, premium and indemnity structures are likely to vary significantly among crops and regions (Hussain, et al., 2002).

Tubail et al., showed that the use of wastewater for agricultural irrigation is accepted by 76% of the sample in Gaza northern area and 89% in southern area (Tubail et al., 2003).

3.12 Soil aquifer treatment (SAT)

Soil Aquifer treatment is an infiltration of the sewage effluent into the aquifer, and the natural movement of the effluent within the groundwater acts as a natural filter to treat wastewater, decreasing BOD, TSS, bacteriological presence and metal concentration. Since the soil and aquifer are used as natural treatment, such system is called Soil-Aquifer Treatment system or SAT system. Soil-aquifer treatment is, essentially, a low-cost, advanced wastewater treatment system. It also has an aesthetic advantage over conventionally treated sewage in that water recovered from a SAT system is not only clear and odor-free but it comes from a well, drain, or via natural drainage, rather than from a sewer treatment plant. Thus, the water has lost its connotation of sewage and the public see the water more as coming out of the ground (groundwater) more than as sewage effluent. This could be an important factor in the public acceptance of sewage reuse schemes (PWA, 2009).

3.12.1 Efficiency of SAT

SAT has an excellent capacity for removing from the effluent a wide range of contaminants by a variety of processes like the followings:

- The soil-aquifer system viewed as a huge reactor where both biological and physico-chemical processes occur
- The biological and physico-chemical processes perform in conjunction with one another. Consequently, the purification capacity has not been affected by time
- With proper operation and maintenance and adequate monitoring, the SAT system should be considered an extremely attractive and reliable method for effluent reclamation and reuse in areas where suitable conditions exist for groundwater recharge via spreading basins (Shafdan WWTP, Israel, 2010).

CHAPTER4

RESERCH METHODOLOGY

- **Technical Parameters**

Due to the fact that Groundwater is the most significant resource in the Gaza Strip as it is the only natural source of fresh water. Therefore, groundwater contamination can pose serious health and economic threats to the population that relies on this water for drinking, agriculture, and industry uses. The sampling locations and frequency selected included, wastewater samples. The wastewater quality parameters including pH, electrical conductivity (EC), total dissolved solids (TDS), Cl⁻, NO₃⁻, Total coliform and Fecal coliform are the main parameters detected in principle for treated wastewater.

4.1.1 Samples Collection

Several wastewater samples were taken during the study period. These samples were analyzed in Bir-Zeit laboratory, Gaza branch. The results were compared with Palestinian Standard for ensuring it's compatible to be used in irrigation. The samples were taken from the inlet, outlet of KYWWTP and recovery wells to test the treatment efficiency . Due to the importance of the wastewater properties on agricultural practices, it is necessary to determine its characteristics before consumption. Its physical, chemical and biological properties need to be properly conserved. Where wastewater analyzed according to American Public Health Agency (APHA, 1995).

- **pH**

Combined portable PH-meter (HI 8424) was used for measuring pH, Before measurements, the meter was calibrated and verified to make sure that it is in good working order. To determine the pH value, probes were immersed into the sample to be tested and the mode of pH was selected by pressing the range key until the display changes to pH. Electrode was stirred gently and stands a few minutes to adjust and stabilize. The display was showed the pH value automatically compensated for temperature.

- **Electrical Conductivity (EC)**

Measuring conductivity was done by using EC meter (El-Hanna, TH-2400), that measuring the resistance occurring in an area of the test solution defined by the probe's physical design. Voltage is applied between the two electrodes immersed in the solution, and the voltage drop caused by the resistance of the solution is used to calculate conductivity per centimeter. The

display was showed the EC value automatically compensated for temperature. The basic unit of measure for conductivity is the Siemens (or mho), the reciprocal of the ohm in the resistance measurement. Because ranges normally found in aqueous solutions are small, micro Siemens/cm. EC was measured for soil and wastewater samples.

• Chloride Cl^-

10 ml of wastewater sample or a suitable portion diluted to 100ml is placed into an Erlenmeyer flask and 1ml potassium chromate solution added. The mixture is then titrated against a white back ground with silver nitrate solution until the color changes from greenish yellow to reddish brown. Blank sample with distilled water is treated in the same way as the sample. The same was performed for soil extract.

• Nitrate NO_3^-

Nitrogen in soils occurs in many forms, both organic and inorganic. The former fraction, composed mostly of plant and microbial remains, is variable in composition. With increasing aridity, however organic and total soil N tends to decrease. The inorganic phase of soil N is composed of ammonium (NH_4^+), nitrate (NO_3^-), and nitrite (NO_2^-) forms. The NH_4 and NO_3 forms are routinely measured in soil laboratories, as they reflect the extent of mineralization, and are the forms of N taken up by plants. Thus, Nitrate is measured by a spectro-photometric method (using chromotropic acid). Chromotropic acid spectrophotometrically method is quite rapid, used originally for wastewater and later for soils.

• Biochemical Oxygen Demand (BOD_5)

The most widely used parameter of organic pollution applied to wastewater is the 5-day BOD (BOD_5). The BOD_5 is usually exerted by dissolved and colloidal organic matter and imposes a load on the biological units of the treatment plant. Oxygen must be provided so that bacteria can grow and oxidize the organic matter. An added BOD_5 load, caused by an increase in organic waste, requires more bacterial activity, more oxygen, and greater biological-unit capacity for its treatment. The determination of the BOD_5 involves the measurement of the dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter. Several dilutions of the wastewater are put into standard BOD_5 bottles with water that has been saturated with oxygen, and contains bacteria. A control bottle is also prepared with only water and bacteria. The bottles are put into a standard incubator for five days; hence this is

called the “Five-Day BOD Test (BOD₅).” The difference in oxygen levels between the control bottle and the bottles with oxygen remaining is used to calculate the BOD₅ in mg/l.

• **Chemical Oxygen Demand (COD)**

The COD test is used to measure the organic matter in industrial wastewater that contains compounds that are toxic to biological life. It oxidizes the reduced compounds in wastewater through a reaction with a mixture of chromic and sulfuric acid at high temperatures. There is another COD test using permanganate as the oxidizing agent but this test will give lower values and is not directly relatable to the standard COD test. The COD of wastewater is, in general, higher than that of the BOD₅ because more compounds can be chemically oxidized than can be biologically oxidized. For many types of wastewater, it is possible to correlate COD with BOD₅. This can be very useful because COD can be determined in 3 hours, compared with 5 days for the BOD₅. Once the correlation has been established, COD measurements can be used to good advantage for treatment-plant control and operation. The ratio of COD to BOD₅ is usually 1.5: 2 for industrial wastewater containing biodegradable material (e.g. Food Industry). For wastewaters with ratios higher than 3, it is assumed that some oxidizable material in the sample is not biodegradable. No biodegradable material sometimes is called refractory and found mainly in wastewater from chemical, pulp and paper industries.

• **Total Suspended Solids (TSS)**

Analytically the total solids content of a wastewater is defined as all the matter that remains as residue upon evaporation at 103 to 105 °C. Matter that has a significant vapor pressure at this temperature is lost during evaporation & is not defined as a solid. Settable solids are those solids that will settle to the bottom of a cone-shaped container (called an Imhoff cone) in a 60-minute period. Settable solids, expressed as mg/l, are an approximate measure of the quantity of sludge that will be removed by primary sedimentation. Total solids, or residue upon evaporation, can be further classified as non-filterable (suspended) or filterable by passing a known volume of liquid through a filter. The filterable-solids fraction consists of colloidal and dissolved solids. The colloidal fraction consists of the particulate matter with an approximate size range of from 0.001 to 1µm. The dissolved solids consist of both organic & inorganic molecules and ions that are present in true solution in water. The colloidal fraction cannot be

removed by settling. Generally, biological oxidation or coagulation, followed by sedimentation, is required to remove these particles from suspension. The suspended solids were found in considerable quantity in many industrial wastewaters, such as cannery and paper-mill effluents. They are screened and/or settled out at the treatment plant. Solids removed by settling and separated from wash water are called sludge, which may then be pumped to drying beds or filtered for extraction of additional water (dewatering). Each of the categories of solids may be further classified on the basis of their volatility at $550 \pm 50^{\circ}\text{C}$. The organic fraction will oxidize and will be driven off as gas at this temperature, and the inorganic fraction remains behind as ash. Thus the terms "Volatile suspended solids" and "Fixed suspended solids" refer, respectively, to the organic and inorganic (or mineral) content of the suspended solids. The volatile-solids analysis is applied most commonly to wastewater sludge to measure their biological stability.

• **Fecal Coliform (FC)**

For estimation of FC bacterial populations, The Membrane Filtration (MF) 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 saturated with a culture medium that is selective for coliform growth (CFU). The pad dish containing the filter and pad is incubated, upside down, for 24 hours at the appropriate temperature ($44.5 \pm 0.2^{\circ}\text{C}$). After incubation, the colonies that have blue color are identified and counted using a low-power microscope. Few colonies from each plate were picked and biochemical tests were performed to confirm the identity.

4.1.2 Data Analysis

All data (previous and obtained from test program) were entered as Microsoft Excel sheet. Results were represented on figures and curves to deduce the trend of parameters development over the desired period from 2011 till 2012.

4.2 Socioeconomic Analyses

A structured questionnaire was developed to know farmers' perceptions on wastewater and current scenario of its use in agriculture in Almawasi- Khan Younis areas and. The questionnaire included questions to identify the attitudes and knowledge of the farmers

concerning the use of wastewater for irrigation. It addressed the cropping patterns, farm inputs (water, pesticides, fertilizers) and outputs (yield), irrigation practices (water sources, methods), impacts of wastewater irrigation on local environmental health, and farmers' attitudes in using wastewater for irrigation. Using the questionnaire, a farmer-survey was executed in Al-Mawasi- Khan Younis.

4.2.1 Data Collection Tools

A formal survey of family farms was conducted using a standardized questionnaire. The questionnaire was designed to capture information on family characteristics (family size, age, sex composition and educational status), type and amount of resources owned (labor, land, etc), resource use strategies (on farm, off-farm and household), production processes, living standard of the families (including social as well as economic indicators) and family problems and objectives. Additionally, special emphasis was given to the use of treated wastewater for irrigation. This part includes knowledge, acceptance and willingness to pay for treated wastewater. The questionnaire included the characteristics that may affect farmer's decision toward the use of treated wastewater in irrigated agriculture. Additionally it investigated the reasons for accepting and rejecting the use of treated wastewater according to farmers view, An important step also investigate the economic benefits by using treated wastewater so asked all of respondent farmers who use wastewater reuse in irrigation sell their products in local markets.

4.2.2 Descriptive analysis

To study the acceptance and willingness to use treated wastewater as an option to existing, a social survey was conducted on farmers. The survey studied wide range of socioeconomic indicators to investigate the differences between farmers who accept and reject the use of treated wastewater in irrigated agriculture.

4.2.3 Causality analysis

SPSS software was used to run the following logistic regression:

Let Y be a dichotomous variable which is defined as

$$Y = \begin{cases} 1 & \text{for those have lung cancer} \\ 0 & \text{for those do not have lung cancer} \end{cases}$$

and $p = \Pr(Y=1 | X_1, \dots, X_k)$.

$$P = \frac{1}{1 + \exp[-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k)]} \quad (1)$$

$$\text{and } \hat{P} = \frac{1}{1 + \exp[-(\hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \dots + \hat{\beta}_k X_k)]}$$

$$\text{Note: With no predictors, } \hat{p} = \frac{\sum_{i=1}^n Y_i}{n} = \bar{Y}$$

The relationship of a dichotomous variable with its predictors is quantified with the odds ratio. Since $\text{odds}(D) = \frac{\Pr(D)}{1 - \Pr(D)}$, $\text{odds}(Y=1) = \frac{P}{1 - P}$.

The “logit” is the natural log odds of the event, $Y=1$, that is,

$$\text{logit}[p] = \ln[\text{odds}(Y = 1)] = \ln \left[\frac{p}{1 - p} \right]$$

$$\text{logit}[p] = \beta_0 + \beta_1 X_1 + \dots + \beta_k X_k \quad (2)$$

Where;

Pi = the probability of social acceptance for the I the farmer.

1-Pi = the probability of social unacceptance to pay for the I the household

B0 = the intercept

B1,B2,B3,B4 = the slope parameters of the model which measures the change in logit [p] for a unit change in the explanatory variables Hence, it tells how the log-odds in favor of social acceptance as the value of the variable X_i changes by a unit.

Note: The logits can take on any values between $-\infty$ to ∞ while $\Pr(Y=1)$ can only take on values between 0 and 1.

$$\text{Odds}(Y=1) = e^{\beta_0 + \beta_1 X_1 + \dots + \beta_k X_k} \quad (3)$$

This formulation helps in clarifying the meaning of the maximum likelihood coefficients:

e^{β_i} gives the change in the odds for Y when there is a unit change in the predictor X_i , $i = 1, \dots, k$

CHAPTER 5

RESULTS & DISCUSSION

5.1 Introduction

The main objective of this study is to investigate the quality of KYWWTTP effluent and recovery wells, and to evaluating the impact of using treated wastewater on quality of resources and efficiency of farming activities for short-term (two years). To achieve the objectives of the study, the national and international reuse guidelines were reviewed and compared with the case in KYWWTTP. 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.

5.2 Applied Wastewater Quality

In treated effluents, the physical and chemical constituents need careful consideration in order to evaluate or detect possible short or long-term effects on soils and crops from salts, nutrients and trace elements (Kathijotes, 2006). Moreover, the risk of reuse may attribute by wastewater application will be investigated based on criteria illustrated in Table (5.2) developed by Kathijotes, 2006 as well as Palestinian Standards (PS), Environmental Protection Agency (EPA, 2003), and Food & Agriculture Organization (FAO, 1985, 1992) see in Appendixes(4).

5.2.1 Physical Properties

- **pH**

The pH values of wastewater can be affected by the source of water, the season, type of wastewater and the treatment process (Kiziloglu, 2007). For pH values indicate that the applied wastewater has alkaline pH values accounted for 7.98, 7.65, 8.02, 7.81, 7.78, and 7.69 for the months Jan, Feb, Mar, Apr, May and June 201, respectively. Meanwhile, the pH of recovery wells showed no changes from the resource of the effluent as shown in Figure (5.1). According to EPA, 2003 and FAO, 1985 guidelines these values are in the normal and safe range pH (6.5- 8) for wastewater reuse for irrigation purposes. The importance of the effluent pH in irrigation is not limited to physical characteristics of the soil, but it can alter and affect the nutrient mobility and availability as well. Therefore it classified as important parameter for effluent reuse.

Results also indicate that pH values decrease with time, this decrease may be attributed to the increase of organic loads and decline of its removal efficiency as the treatment plant are heavily overloaded year after another (Al Khaldi, 2006). It may also results from the formation of volatile acids and carbon dioxide from anaerobic digestion of organic matter. Considering the reduction of the pH values which reached to nearly 7 in the recovery wells and the guidelines, it still in the safe range. As shown in Figure (5.1) the change of the pH is never over 10% within two years of monitoring.

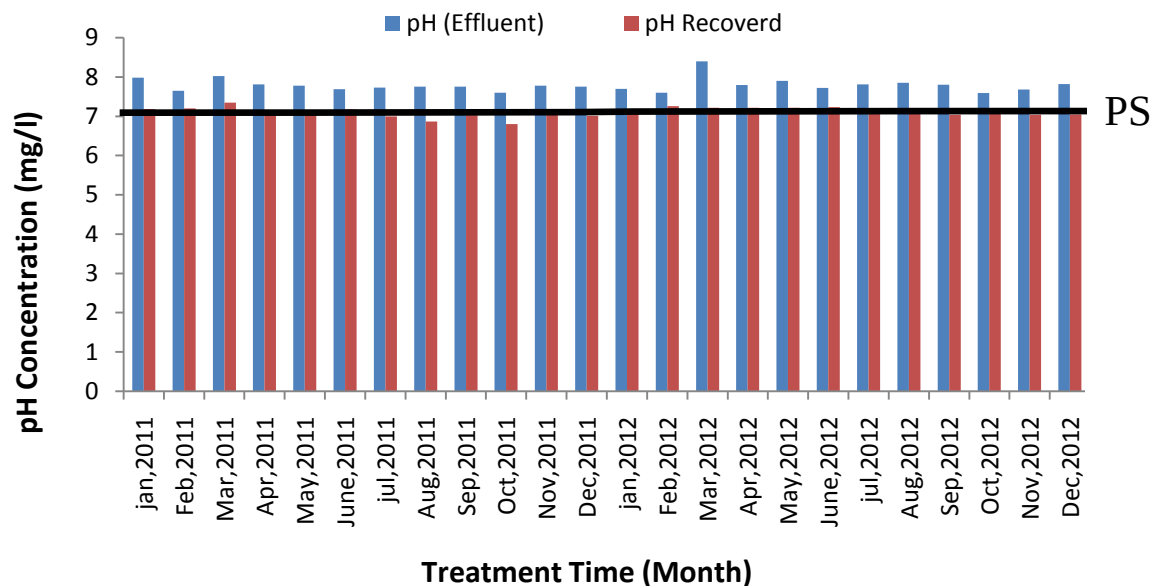


Figure 5.1: pH of the effluent, recovery wells and the changes by time.

- **Electrical Conductivity (EC) and (TDS)**

The salinity of the effluent could be measured by two parameters, total dissolved solids (TDS) and electrical conductivity (EC). Refer to the Total Dissolve Solids content of water sample .Electrical Conductivity (EC) is the numerical expression of the ability of aqueous solution to carry an electric current. A direct relationship between Electrical Conductivity and TDS is known .This makes determination of TDS easier as EC which can be measured readily with an instrument.

TDS = 0.62 EC, where: EC = Electrical Conductivity, $\mu\text{S}/\text{cm}$. TDS = Total Dissolved Solids, mg/l . and EC = Electrical Conductivity, $\mu\text{S}/\text{cm}$.

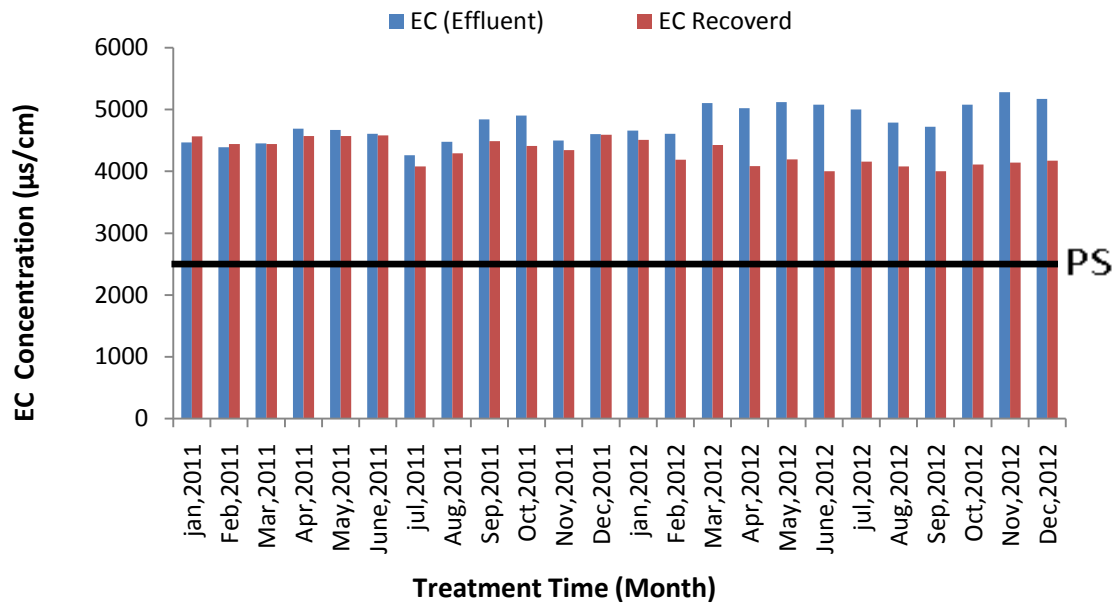


Figure 5.2: EC values for effluent wastewater, and recovery wells and the change with time.

Electrical conductivity in applied wastewater was ranging from 4260- 5280 $\mu\text{s/cm}$ Values of EC while electrical conductivity of recovery wells ranged from 4000 $\mu\text{s/cm}$ to 4573 $\mu\text{s/cm}$ as shown in Figure (5.2) Based on FAO, 1985 guidelines for salinity concentrations EC has moderate restriction on use at current EC level and it can be used for irrigation with no severe risks in case of high drainage soil. 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 $\mu\text{s/cm}$. EPA, 2003 guidelines divided the applied wastewater into five main classes based on EC and TDS values as in Table (5.1). The range of salinity is classified as 4, where the effluent should be used for special tolerant crops with care of drainage system.

It is worth to mention that the secondary treatment in the Gaza Strip has negligible influence on the electrical conductivity; the salinity of wastewater is associated with the drinking water which is mainly abstracted from ground aquifer. Care should be taken when wastewater from different places in Gaza Strip is being used as high variability of water quality exists even if it's small area.

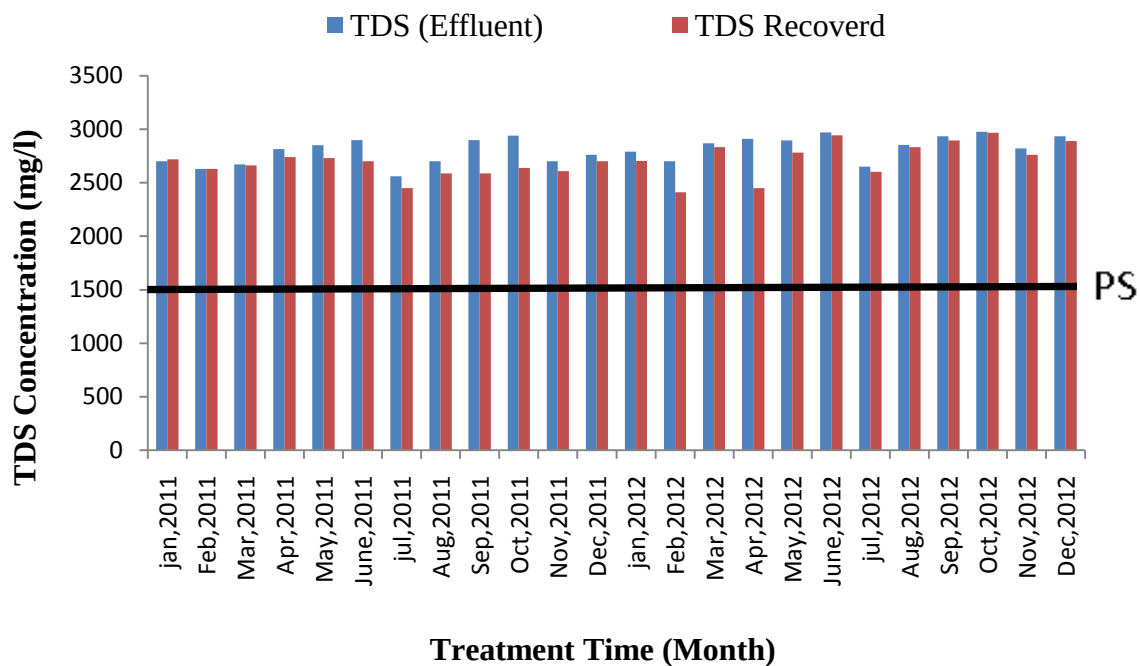


Figure 5.3: TDS in the effluent and recovery wells and the change with time.

The results of effluent Total Dissolved Solids (TDS) values and the trend of the TDS of the effluent of the KYWWTP during the study period are shown in Figure (5.3). The results show an increase in the average effluent TDS ranged from (2560 – 2970 mg/l in the study period. Dissolved solids are a portion of organic and inorganic solids that is not filterable and consists of two main categories: Fixed (noncombustible or mineral components of total dissolved solids) and Volatile (combustible or organic components of total dissolved solids). Normally, solids smaller than one mill micron are fall in this category and in a concentration range of 250-800 mg/l (Qasim, 1999). Considering the period from the year 2011 to 2012, the values of the effluent TDS are increasing with time and this is mainly due to the deterioration of water quality of the aquifer, which is reflected on the incoming influent to KYWWTP as Figure (4.3) showed the trends of both effluent and recovery wells.

The values of TDS increased a little when passing through the treatment process due to evaporation which is clear in summer months.

The TDS of recovery wells (treated effluent by Soil Aquifer Treatment) showed no changes from the resource of the effluent, It is obvious the SAT technology has no effect on the

salinity level of in-out effluent. The main observation is that, the groundwater aquifer has as salt as the effluent wastewater. Therefore, the effect of dilution is not playing any role toward the improvement in effluent quality.

Table 5.1: Salinity classes of irrigation waters and salt tolerant plants (EPA, 2003).

Class	TDS (mg/l)	EC ($\mu\text{s/cm}$)	Comments
1	0 -175	0 - 270	Can be used for most crops on most soils with all methods of water application 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 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 restricted to salt tolerant crops or emergency us.

- **Biochemical Oxygen Demand (BOD₅)**

As shown in Figure (5.4), the effluent of BOD₅ is rarely below 100 mg/l, it ranged from 70 - 210 mg/l. These results higher than PS Standards BOD₅ for reuse. Concentration decreased to 70 mg/l in winter months due to the dilution by storm water, whereas higher BOD₅ concentration in Aug. 2012 (210) mg/l. This value shows the difference BOD₅ concentration reduction. These results indicate that the reductions of BOD₅ concentrations were also affected by activities involving microorganisms that can break down the organic compounds and the weather condition. Other researcher (Prab & Udayasoorian, 2007) also confirmed that the reduction of BOD₅ could be caused by oxidation of organic matter in wetlands system that provides energy for microbial metabolism. The organic matter contained in the wastewater provides a substrate for aerobic microbial metabolism and the length of cauterization time could lead to a decrease of BOD concentration in water phase. Figure (5.4) show the results of the average monthly effluent BOD₅ and removal efficiency versus BOD recovered during the study period. The results show the dramatic increase of the average flow rate from so the

same time, the average BOD₅ effluent increased from 30 mg/l to 140 mg/l in the year 2011 and from 95mg/l to 210mg/l in 2012. A considerable variation between summer and winter values can be observed. Figure (5.4) presents the monthly series of BOD₅ results from recovery wells it's from 10mg/l to 41.3mg/l and from 56.2mg/l to 90.3mg/l in 2012. The removal efficiency was decreased from 89% to 41% in the study period.

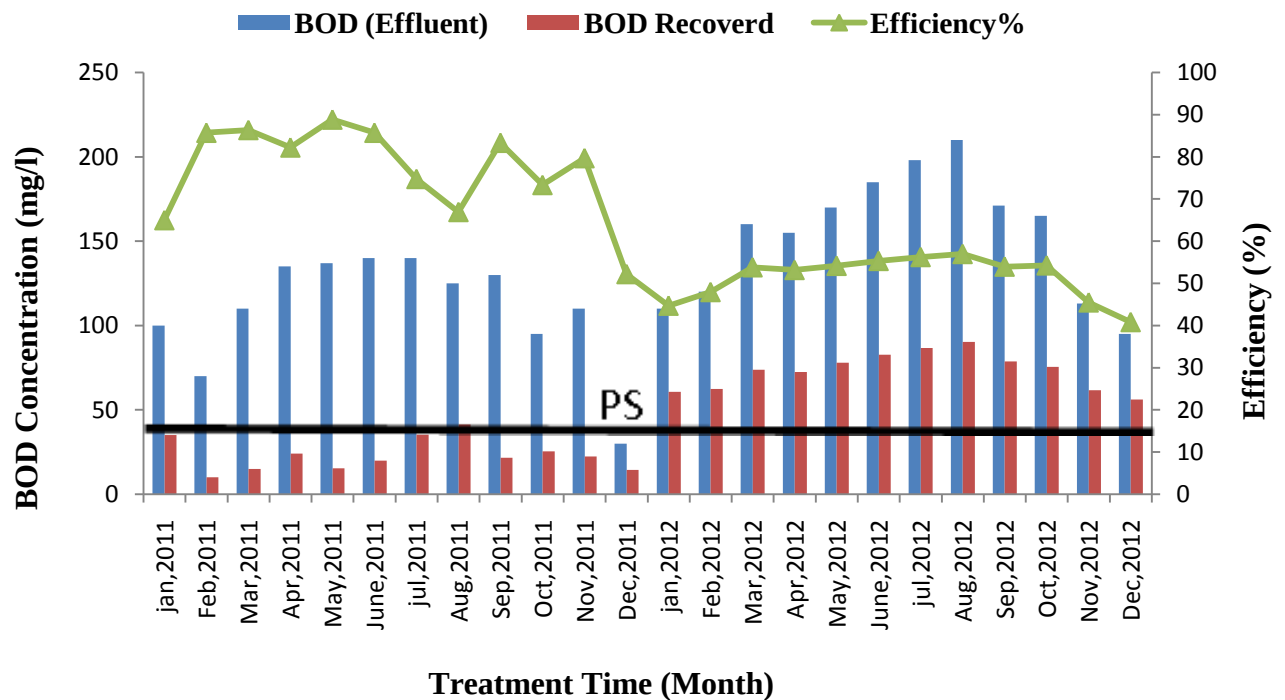


Figure 5.4: BOD Concentration of the effluent wastewater the recovery well and BOD removal efficiency by using the recovery wells.

The Biochemical Oxygen Demand (BOD₅) is the most important parameter in the treatment process design and effluent discharge or reuse (Qasim, 1999). Lowering of BOD₅ is both a physical process by way of settling of organic particles and a biochemical process through decomposition and mineralization of organic and inorganic compounds (Reed, 1995). In a good designed system, aerated lagoons can reliably produce an effluent with both biological oxygen demand (BOD₅) and TSS less than 30mg/l if settling is provided at the end of the system (EPA, 2002). A combined system in which the process includes a fixed film reactor followed by a contact channel 10-15% of the size of an aeration basin of a conventional activated sludge plant will have a removal efficiency of BOD₅ up to 85% (Qasim, 1999). The

BOD₅ values for influent and effluent of KYWWTP generally increase in the summer months than in the winter months. This is due to the increase in the water consumption. The effluent BOD₅ value is increasing with the annual increase in the influent quantity and the most recent tests taken. The explanation for this increase in the value of effluent BOD₅ is that the KYWWTP is already hydraulically over loaded of more than 70% of the designed hydraulic load, and leads to decrease in the retention time of the sewage water when passing through the plants components, which reflects the need to find a solution to retain the original designed retention time for the treatment process and hence obtain the required values of the BOD₅.

- **Chemical Oxygen Demand (COD)**

The Chemical Oxygen Demand (COD) is another important factor highlighted in this research for the performance of KYWWTP. The average values of the effluent COD and removal efficiency against flow rates of KYWWTP and the trend of the removal efficiency during the study period are demonstrated in Figures (5.5). The results show the higher trend. Increasing the hydraulic load of the plant was reflected negatively on removal efficiency and increases the average effluent COD concentration of the plant. The COD test is rarely used in effluent discharge control, but primarily in assessing the strength of trade or industrial effluents (Tchobanoglous & Schroeder, 1999). For the reason that the COD test is a simple chemical assay, it is easy to point out its drawbacks and limitations. The results showed that the average COD values for effluent increased in Nov. (2011) 400mg/l and Aug. (2012) 680mg/l and the COD removal efficiency decreased, which indicates a poor performance of KYWWTP due to the increasing hydraulic load. The most recent tests of KYWWTP lab show that the effluent values of the COD ranges between 140mg/l to 680mg/l indicating that the removal efficiency of COD was less than 85% by December (2011), while the results of COD from recovery wells range between 20mg/l to 241mg/l apparently boost the idea of approaching to wastewater reuse application from KYWWTP by recovery well techniques. The numeric value of the COD removal efficiency is less than the BOD because of the non removal of the non- degradable fraction of the COD. In a combined aeration lagoons –trickling filter system, the COD removal could reach up to 90% (Qasim, 1999). Values obtained from the tables in annex 1 for influent COD test simply showed a relation of 2:1 of COD: BOD which is complying with theoretical values of COD: BOD ratio of municipal settled sewage (Horan, 1990). Values obtained for effluent for COD: BOD ratios show a relation of 3:1. This is

owing to the fact that biodegradable fraction of the waste decreases through the biological treatment whereas the non-biodegradable fraction remains unchanged (Horan, 1990). In view of its simplicity and rapidity, the COD test is the most suitable assay for the determination of the strength of both raw and treated wastewater.

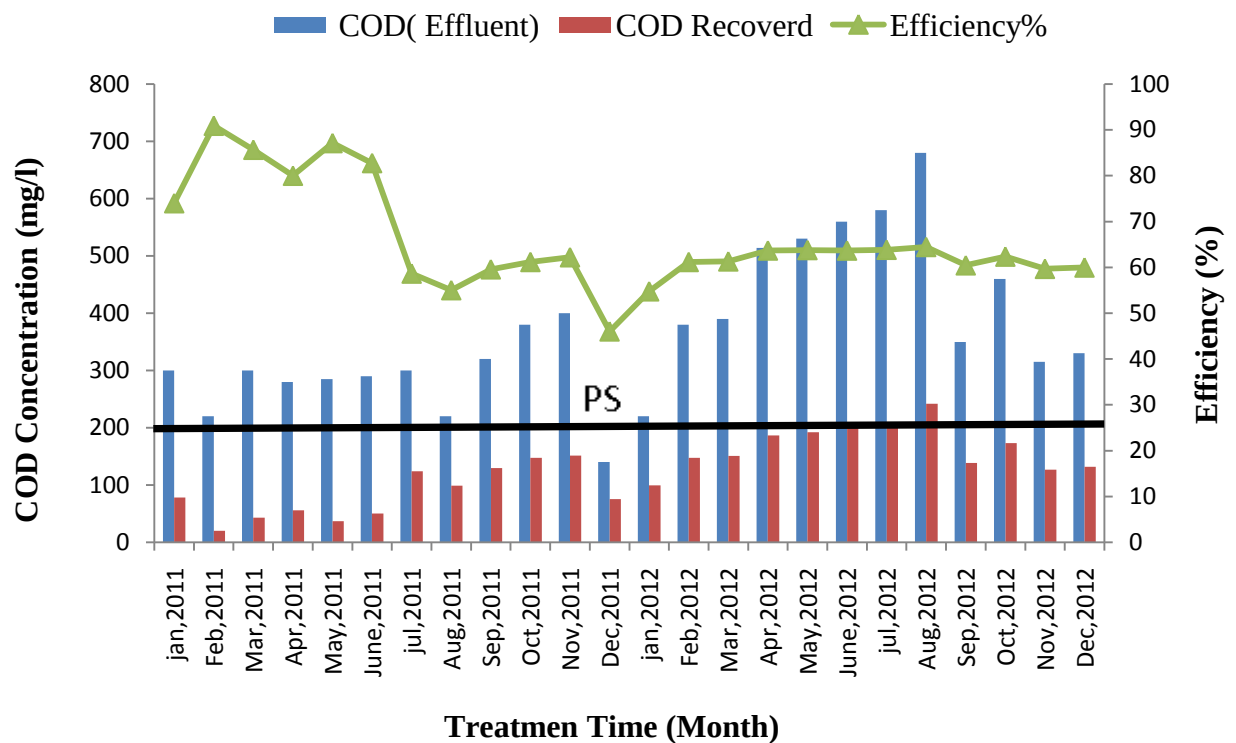


Figure 5.5: COD of effluent wastewater and the recovery well and the removal rate due to the recovery wells.

- **Total Suspended Solids (TSS)**

The results of effluent TSS average values and the trend of the TSS removal efficiency of the KYWWTP during the study period are shown in Figure (5.6), showed that the average effluent TSS increased from an average of about 40mg/l in December, (2011) to 171 mg/l in May, (2012). The percentage of TSS removal efficiency of the system was decreased from about 92% in June (2012) to less than 64% in December, (2011). Theoretically the value of TSS should not exceed 80% of the value of BOD in the wastewater (Horan, 1990).Consequently, this will reduce the hydraulic capacity of KYWWTP (retention time) and the removal efficiency of the TSS .The organic material deposited on the bed of the treatment process is subject to biodegradation, which results in a depletion of the oxygen source at a faster rate than it is supplied with. This material is therefore subject to anaerobic breakdown, which results in the production of methane and toxic hydrogen sulfide gases. The clogging of the soil of the recovery wells by time lead to the decrease of TSS removal efficiency. For the purpose of wastewater reuse in irrigation, the limited value is 45 mg/l and could be less in case of drip irrigation system.

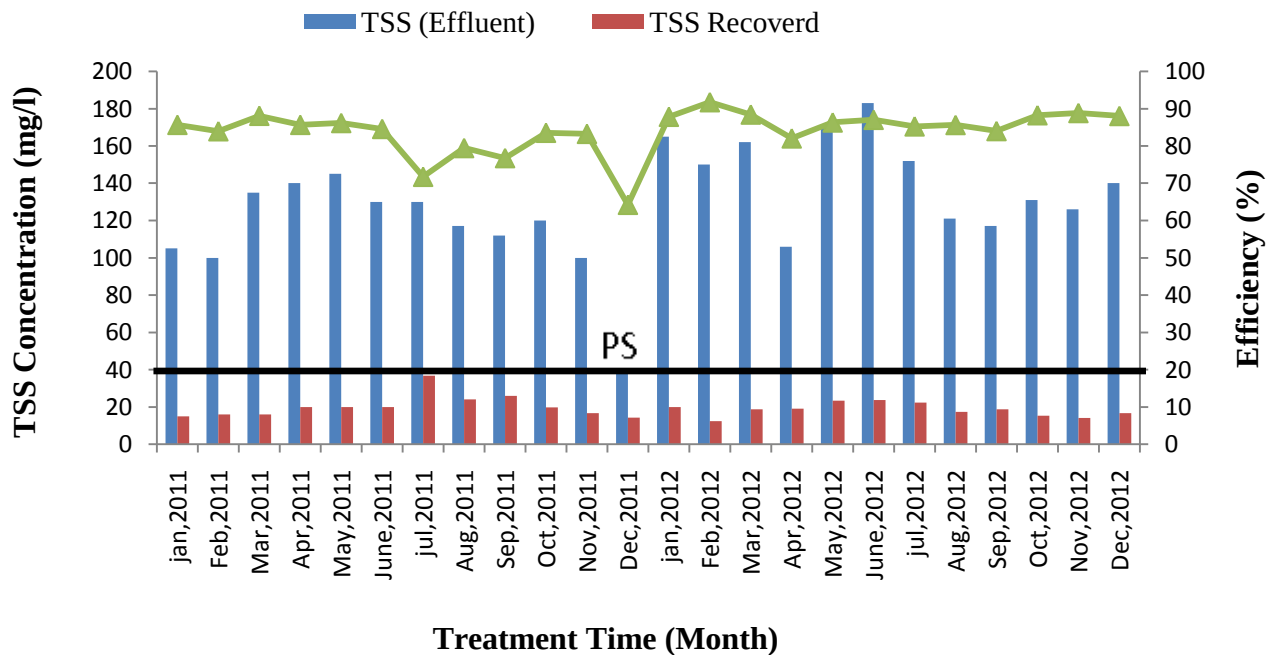


Figure 5.6: TSS of effluent wastewater, recovery wells and the removal efficiency

5.2.2 Chemical Properties

- **Nitrate (NO_3)**

The total nitrogen in wastewater is often referred as Total Kjeldahl Nitrogen (TKN). It is well known that during any biological treatment process, up to 30% of the total nitrogen is removed in cell synthesis by ammonification, in addition to that removed during the sedimentation processes. This could be the reason of which nitrate in applied water is within the percentage as shown in Figure (5.7) the NO_3 values ranged from 0.98 to 3.1mg/l in the effluent wastewater. While the values of NO_3 from the recovery wells ranged from 15mg/l to 51.6mg/l. It is noticed that nitrate level of applied wastewater increases with time and this may be due to the efficiency of treatment plant as the organic load increases with time. Moreover as it was stated high NO_3 has no severe impact on crops but it may leaches to the ground aquifer. The high nitrate concentration in the recovery wells originate from the already high nitrate groundwater. Nitrate plays essential role in plant growth, therefore, the limitations are not restricted, but in some plant growth stages nitrate is not preferable. Currently farmers use groundwater for irrigation which has nitrate concentration more than 100 mg/l in Rafah and Beit Lahia without seeing any reduction in the yield. Using the recovery wells in the study area with high nitrate concentration will need special regulation to limit the input of mineral nitrogen fertilizer. It is worthily to use the treated effluent directly for irrigation if we consider the increase of treatment plant efficiency toward BOD and TSS removal.

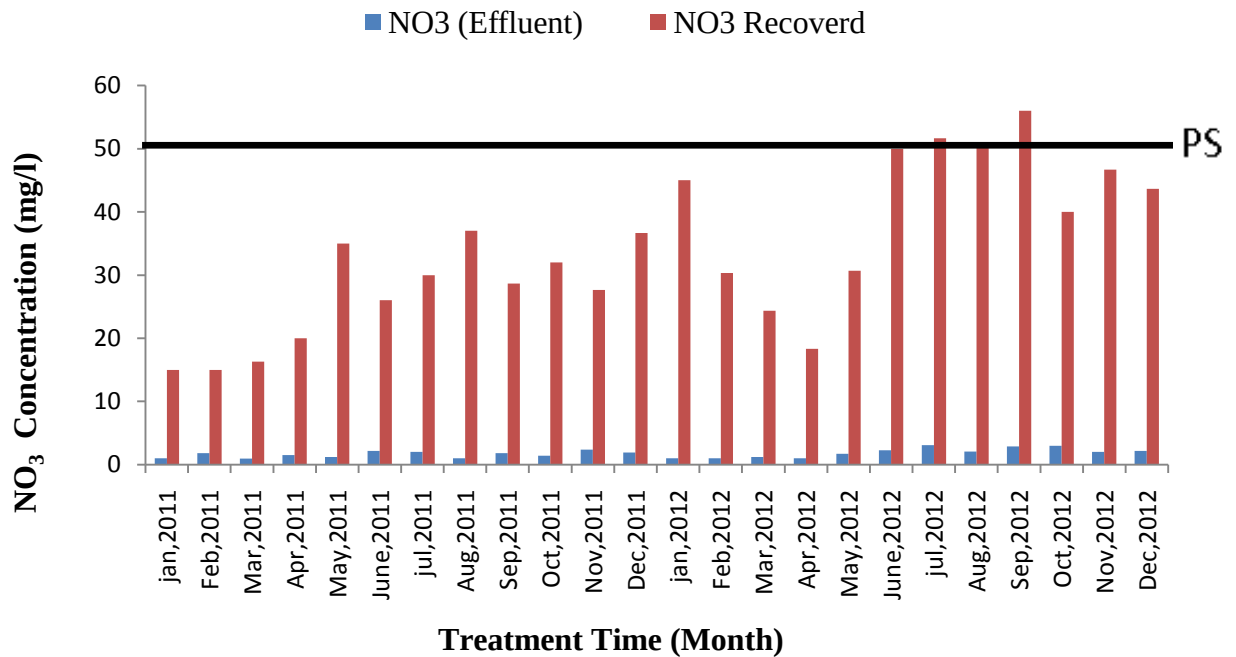


Figure 5.7: NO₃ Concentration in the effluent and the recovery wells.

- **Chloride (Cl)**

It is known that the chloride concentration all over the Gaza Strip aquifer is higher than recommended by international standards except for the northern area as the chloride concentration is within the acceptable range by different standards for drinking purposes (around 250mg/l). It was clearly noticed in Figure (5.8) that average Cl value for effluent (983.3) mg/l, While the average concentration of Cl for recovery wells (860.7) mg/l these results higher than Palestinian Standard (500) mg/l.

The higher concentration of chloride in the treated wastewater is perhaps due to human excrement and to the evaporation of water in the pond during the summer season not to chlorination of municipal water (Al-Khashman, 2013). Moreover, the salinity of the groundwater generates from the sea water intrusion which characterized by high Cl and Na ions.

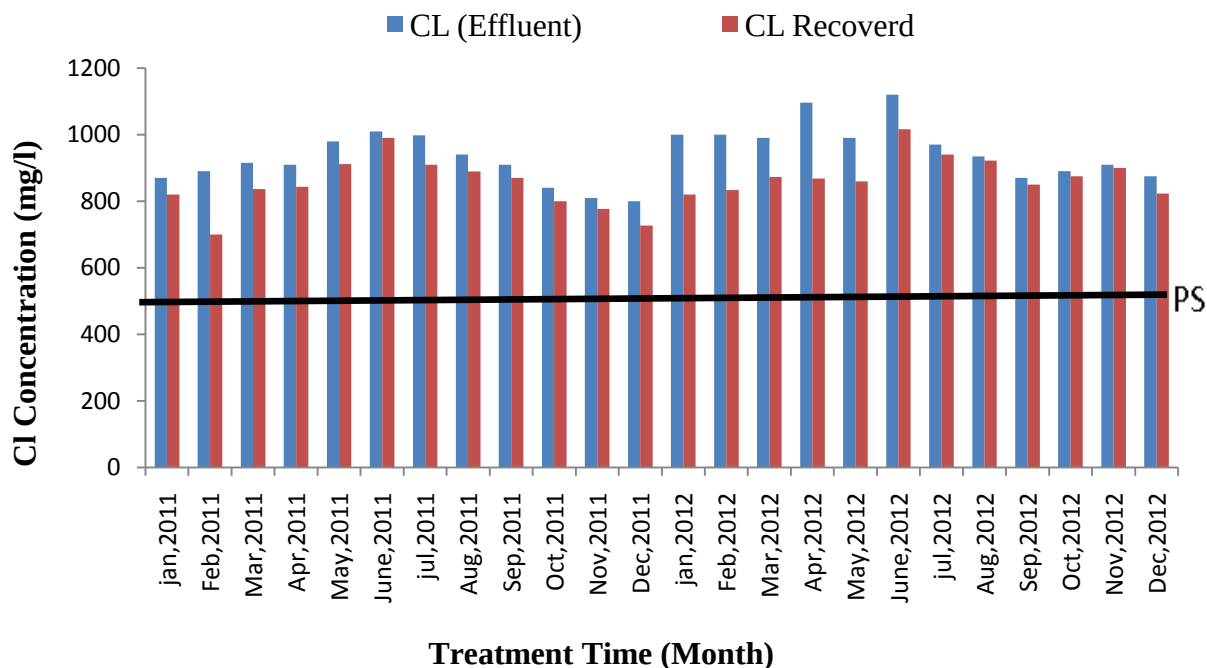


Figure 5.8: Cl Concentration of effluent wastewater, recovery well and the removal efficiency.

- **Ammonium Nitrogen ($\text{NH}_4\text{-N}$)**

Nitrogen in the inflow of a municipal sewage treatment plant is largely present as organic ammonium (urea, proteins, etc.) and ammonium nitrogen. The exact relationship of the two parameters to each other depends on various factors, including the length of the sewage network, which is where the conversion of org. to $\text{NH}_4\text{-N}$ begins. The process of ammonification continues in the sewage treatment plant, so that most of the nitrogen in the inflow to the aeration tank is in the form of $\text{NH}_4\text{-N}$. During the biological wastewater treatment stage, $\text{NH}_4\text{-N}$ is converted with the help of added oxygen to $\text{NO}_2\text{-N}$ and then $\text{NO}_3\text{-N}$. The microorganisms responsible for nitrification (Nitrosomonas and Nitro- bacter) are however, extremely sensitive for oxygen. They require constant temperatures of not less than 12°C , together

The reduction of NH_4 in the recovery wells can be explained as the infiltration of the treated effluent with high NH_4 exposed to nitrification process which reduces the NH_4 and lead to increase in NO_3 concentration together with a favorable C:N:P ratio and an adequate supply of added oxygen.

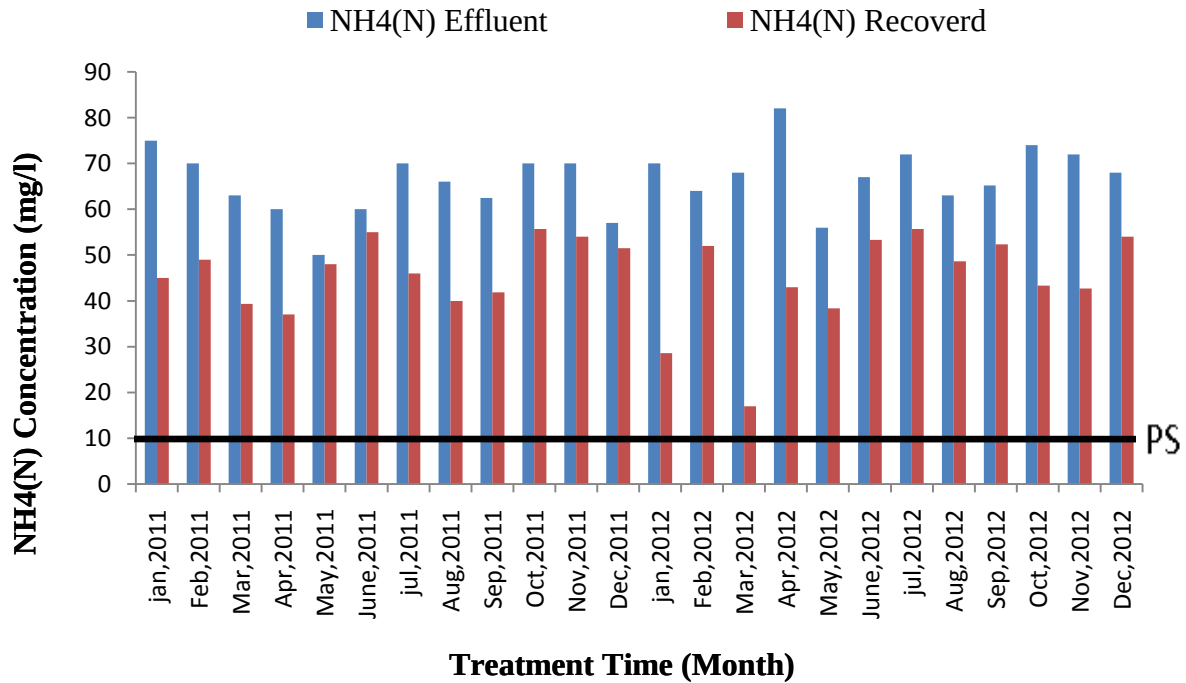


Figure 5.9: NH₄-N Concentration effluent wastewater, recovery well and the removal efficiency

5.2.3 Biological Quality of Wastewater

Fecal coliform (FC) were investigated as indicator parameters for biological contamination of wastewater. Table (5.2) presented the average values of effluent fecal coli form of KYWWTP in the study period. The average value of FC in the effluent is 3×10^4 cfu/100cm. which indicates a very low microbiological removal efficiency of KYWWTP. But the values of FC of recovery wells show concentrations are lower than the WHO standards which apparently boost the idea of approaching to wastewater reuse application from KYWWTP by recovery well techniques.

Results indicated that average values of FC in applied wastewater in KYTTP were higher than PS and WHO standards (1000 FU/100ml) as in Table (5.2).

Comparison of average FC values with time revealed significant increase of FC values with time. This increase attributed to the increased organic loading as well as the inadequate design

of the maturation pond in KYWWTP which could be the main reason of the high FC level. The same results was obtained by (Khaldi, 2006) as he concluded that the BLWWTP effluent cannot be used for unrestricted crops from biological quality point view and the plant needs more disinfection units.

Table 5.2: FC Concentration in effluent wastewater, recovery wells.

Parameter	Palestinian Standard	Effluent	Recovery wells
Fecal Coliform	(1000 FU/100ml)	3×10^4 cfu/100cm	0 - 57

5.3 KYWWTP Effluent and Recovery Wells according to PS Standards

According to Palestinian Standards most of effluent parameters from KYWWTP is not within the acceptable range, while in recovery wells showed that's produces much better quality. Table (5.3) illustrates the acceptable range of many parameters in effluent and recovery wells.

Table 5.3: Palestinian Standards for irrigated wastewater

Group	Parameter	Palestine Standards (PS)	Effluent	Recovery Wells
Sanitarian aspects	FC (CFU/100ml)	<1000/100ml	30.000-600.000	0 - 57
Salinity	EC (μ s/cm)	2.5	4.2 - 5.1	4 - 4.6
	TDS (mg/l)	1500	2810	2701
Physical quality	pH	6.5-9	7.6 - 8.4	6.8-7.23
	BOD mg/l	45 / 60	132.5	48.3
	COD mg/l	150 / 200	364.3	125.5
	TSS mg/l	40 / 50	129	19.4
Chemical quality	Cl mg/l	500	938.3	860.7
	NO ₃ mg/l	50	1.78	33.6
	NH ₄ mg/l	10	66.4	45.5

It is clearly noticed that the PS has the same results as international standards guidelines. Results indicated that the average FC level of effluent is much higher than recommended by PS, which means there is a great concern in using this effluent for agricultural irrigation especially in case of raw vegetables and applied water need additional disinfection unit. While the recovery wells produces much better quality of water concerning FC. Practically, the farmers recommended using extra sand filter when they use the effluent wastewater for irrigation to minimize the Fecal and total coliform. Results reveals that salinity of KYWWTP effluent is more than the critical limit assigned by the PS, this support the general conclusion that the water quality in Gaza Strip southern area has low quality related to salinity and there are risks associated from its irrigational use. According to PWA future plans, drinking water quality should be improved, this means decrease the salinity by using Reverse Osmosis RO process for brackish and sea water. At that moment when the domestic water has low salinity, this will reflect on wastewater content of TDS and EC. This is the only approach to minimize the salt content, because the wastewater treatment plant concept are biological treatments and have nothing to do with the salt content of wastewater. It is seen in the near future that the improvement of the biological process of KYWWTP will lead to critical reduction on BOD and COD, while the improvement of drinking water quality will solve the salinity problem of the treated effluent.

5.4 Socio –Economic Aspects

5.4.1 Introduction

The reuse of wastewater for irrigation purposes is not limited to technical issues, but to the social aspects. Many studies treated the technical issues of wastewater reuse in the Gaza Strip concerning the salinity, biological parameters, and the impact on the soil and groundwater aquifer. Farmers in Khan Younis have bad experience with the reuse of wastewater, not only because of its bad quality, but due to the problems of marketing of their products. Once the residents hear of notice that, the crops are irrigated by wastewater this will reflect on the farmer reputation, even if the groundwater is used. Moreover, the reuse projects in the Gaza Strip are mostly financed from the donors as a pilot projects, the involved farmers have not the same importance when the project finished and let to manage alone without support. In the

current research we tried to assess farmer's problems and study the social perspective of wastewater reuse.

The study approach is to reach the farmers by talking face to face, fill questionnaire of their data and our assessment questions.

Socio economic results were obtained from the analyzed questionnaires of the farmers reside in the adjacent areas Al-Mawasi- Khan Younis. A total of 51 questionnaires were completed in the targeted area to study the acceptance and willingness to use treated wastewater, The survey investigated the farm sizes, types of crops in the area, the availability and cost of existing water resources, acceptance and willingness of farmers to pay for treated wastewater

The questionnaire included the characteristics that may affect farmer's decision toward the use of treated wastewater in irrigated agriculture. Additionally it investigated the reasons for accepting and rejecting the use of treated wastewater according to farmers view, the higher yield were the most relevant reasons for accepting the use of treated wastewater. On the other hand exposure to pathogens, contamination of ground water and soil were major concerns leading to reject the use of treated wastewater. (Nassar, 2009) founded the main reason behind the high level of acceptance to use treated wastewater for irrigation includes increasing salinity level in the local agricultural wells , increasing fuel price and maintenance cost. The majority of the respondents are willing to use restricted water for irrigation but were reluctant on using unrestricted water for the same purpose. While the majority believes that the fee should be less than that of fresh water for both restricted and unrestricted water (Ghanem, 2012). In addition to their general willingness to pay for reclaimed water, Most of respondent farmers who use treated wastewater in irrigation have not willingness to pay for receiving treated wastewater in irrigation but all of respondent farmers who use wastewater reuse in irrigation are not accepting any compulsory actions to use treated wastewater in irrigation. The analysis of the farming systems showed that the costs of irrigation constitute a high share of farms' variable cost in agriculture for farmers who don't possess water resources and have fields with no attached water rights (Abu Shaban, 2006).

5.2.2 Personal characteristics

Results shown in Table (5.4) indicate that farming families have big family size of around 7 members and most of them have income less than 1000 NIS (NIS: New Israeli Shaqel) monthly, It also shows that above than 90% of the surveyed farmers don't have another work and totally dependent on farming activities, Which shows the significance of farm income in their livelihood. This agrees with (Nassar, 2010) About 28.4% of all households receive an income of less than 500 NIS/month (NIS: New Israeli Shaqel), 27.3% have between 500 and 1000 NIS/month, 34.1% have monthly between of 1,000 and 2,000 NIS, and 10.2% have an average monthly income of more than 2,000 NIS (1 US\$ = 4.4 NIS). More than 52% of farmers are members of agriculture association and only 7% members of water association. Results show that (83.3%) of farmers has university degrees had more accepting for using treated wastewater. The same results was obtained by (Abu Shaban, 2007) as he concluded that the importance of education status in reflecting the living standard of a family, the educational level of household members may affect the speed of transfer of new ideas. Moreover, higher level of education gives farmers more opportunities to find jobs out of the farm. The table show more details of characteristics.

Table 5.4: Descriptive analysis of Personal Characteristics.

		Social Acceptance					
		Yes		No		Total (51)	
		N	%	N	%	N	%
Education level	Primary	6	33.30%	12	66.70%	18	35.3
	Elementary	1	9.10%	10	90.90%	11	21.6
	Secondary	8	57.10%	6	42.90%	14	27.5
	University	5	83.30%	1	16.70%	6	11.8
	Other	2	100.00%	0	0.00%	2	3.9
Farm Dependency	No	21	44.70%	26	55.30%	47	92.2
	Yes	1	25.00%	3	75.00%	4	7.8
Monthly Income	< 1000 NIS	19	42.20%	26	57.80%	45	88.2
	1000 – 2000 NIS	1	33.30%	2	66.70%	3	5.9
	2000 – 3000 NIS	1	50.00%	1	50.00%	2	3.9
	> 3000	1	100.00%	0	0.00%	1	2.0
Agriculture Association Membership	Yes	10	37.00%	17	63.00%	27	52.9
	No	12	50.00%	12	50.00%	24	47.1
Water Association Membership	Yes	4	100.00%	0	0.00%	4	7.8
	No	18	38.30%	29	61.70%	47	92.2

The logistic regression model will be applied to test the impact of these characteristics on farmer acceptance to use treated wastewater for irrigation where the logistic model tests the following null-hypotheses, there is no relationship between personal characteristics of farmers on social acceptance for using treated wastewater.

The high significance level of the χ^2 statistic in Omnibus Test, which reflects the models' overall Goodness-of-fit, indicates a strong statistical evidence to reject the null hypothesis that none of the hypothesized factors are linearly related to the log of odds of farmer acceptance for using treated wastewater Table (5.4). The percentage of correct prediction is (76.5%). The model indicates that the education levels are better predictor of the social acceptance.

The results show that farmer education is significantly related to social acceptance for using treated wastewater; it has significant positive impact on using wastewater.

Table 5.5: Chi-square test between education level and social acceptance

	B	S.E.	Wald	df	Sig.
Family No.	-.077	.130	.354	1	.552
Education Level	-.864	.372	5.397	1	.020
Another Work	2.467	1.895	1.695	1	.193
Monthly Income	-.680	1.015	.449	1	.503
Agriculture Association Membership	-.651	.713	.834	1	.361
Water Association Membership	21.509	18964.748	.000	1	.999
Percentage Correct = 76.5%					
$\chi^2 = 40.242$ df = 6 sig. = 0.005					

5.4.3 Land Resources

Average land holding per farm is 4.4 dunums. Results shown in Table (5.6) indicate that land is mainly owned as individual ownership 45% and 54% shared ownership. By using Chi square test to investigate the relationship between farm ownership and social acceptance. ($\chi^2 = 0.002$, p-value > 0.05) The low significance level of the χ^2 statistic refer that is no evidence to reject the null-hypothesis (there is no relationship between farm ownership and social acceptance)

Table 5.6: Descriptive analysis of Land resources variables

		N	%
Farm Ownership	Ownership	23	45.1
	Sharing	28	54.9
Total Area	Mean	4.4	
	SD	± 3.5	

Table 5.7: Chi-square test between farm ownership and social acceptance

Cross tabulation				
		Social Acceptance		Total
		Yes	No	
Farm Ownership	Ownership	10 (45.5%)	13 (44.8%)	23 (45.1%)
	Sharing	12 (54.5%)	16 (55.2%)	28 (54.9%)
Total		22	29	51 (100.0%)
Pearson Chi-Square		value = 0.002	df = 1	sig = 0.964

5.4.4 Water resources

The mean of share the treated wastewater for one dunum daily is 6.27m³ daily. In some case the treatment plant faces obstacles that restrict its operation due to technical disorder or power cut. In these cases farmers depend on wells as alternative water resources. Results shown in Table (5.7) that 92% of the investigated cases owns privet wells, 46.8% of them with shallow depth while the remaining 53.2% with deep wells. With regard to the application technology, micro-irrigation such as bubblers or drip-irrigation is usually recommended for reuse schemes. These irrigation methods require certain quality standards of reclaimed wastewater in order to avoid clogging problems. Drip irrigation is most frequently used All of respondent farmers use drip-irrigation for groundwater and treated wastewater.

Labor resources is essential aspect when using treated wastewater as their knowledge and experience on the optimal methods of treated wastewater application to minimize potential negative health hazard of such practice. Capacity building of farmers is therefore vital before adopting any project that aims at providing treated waste water for irrigation. Farmers were asked about type and quantity of received training before starting the use of treated wastewater for irrigation. Results indicated that 64% of the respondents attended theoretical

and practical course on the optimal practices and safety measures of using treated wastewater in irrigated agriculture. These courses followed the standards of PWA, MOA, MOH and EQA

Table 5.8: Descriptive analysis of water resources variables & social acceptance

		N	%
Owns Privet Wells	Yes	46	92.0
	No	4	8.0
Wells Type	Shallow	22	46.8
	Deep	25	53.2
Type Of Water Used	Ground Water	47	94.0
	Treated	3	6.0
Wastewater Basins	Yes	21	95.5
	No	1	4.5
Training Courses	Yes	11	57.9
	No	8	42.1
Kind Of Courses	Practical	1	9.1
	Theoretical	10	90.9
Health Facilities	Yes	14	63.6
	No	8	36.4
		Mean	SD ±
Total Area		4.42	3.564
Quantities Of Wastewater (m³ daily)		6.27	7.899
No. Of Training Courses		1.73	1.486

The logistic regression model will be applied to test the impact of water resources on farmer acceptance to use treated wastewater for irrigation where the logistic model tests the following null-hypotheses, there is no relationship between water resources on social acceptance for using treated wastewater.

The high significance level of the χ^2 statistic in Omnibus Test, which reflects the models' overall Goodness-of-fit, indicates a strong statistical evidence to reject the null hypothesis that none of the hypothesized factors are linearly related to the log of odds of farmer acceptance for using treated wastewater Table (5.8). The percentage of correct prediction is (85.1%). The model indicates that the wells type is better predictor of the social acceptance.

The results show that depth of the wells is significantly related to social acceptance for using treated wastewater; it has significant positive impact on using wastewater.

Table 5.9: Descriptive analysis of water resources variables

	B	S.E.	Wald	df	Sig.
Wells Type	2.310	1.050	4.835	1	.028
Quantity Of Water	.047	.026	3.218	1	.073
Area	-.225	.273	.678	1	.410
Constant	-3.115	1.779	3.066	1	.080
Percentage Correct = 85.1 %					
$\chi^2 = 28.8$ df = 3 sig. = 0.00					

5.4.5 Economic consideration

An important step also investigate the economic benefits by using treated wastewater so asked farmer All of respondent farmers who use treated wastewater in irrigation sell their products in local markets and are not facing any obstacles in marketing their products. The majority of respondent farmers who use treated wastewater in irrigation are not facing any changes in crop quality after using treated wastewater in irrigation and no changes were observed in product marketing prices. Almost (86.4%) of them answered that there are no changes of the products after irrigated by treated wastewater. (90%) of farmers not observe any change of the product quantities and prices. The average quantity of fertilizer used was (3.6, ± 2.1) ton.

Table 5.10: Descriptive analysis of Economic consideration variables

		Count	Column %
Crop Quality Changes After Irrigated	1	3	13.60%
	2	19	86.40%
Product Quantity Changes After Irrigated	0	20	90.90%
	1	2	9.10%
Fertilizer Quantity (Ton/dunums)	Mean	3.6	
	SD	2.1	

5.4.6 Summary of socioeconomic analyses

The socioeconomic analyses intended to assess farmer's perception and attitude towards the use of treated wastewater in irrigated agriculture. Results indicated that farmers are willing to use treated wastewater not only in perennial crops but also in cultivating annual crops. In some cases, farmers were ready to pay for treated wastewater. Technical analysis showed that treatment process faces several challenges and produces a relatively low quality effluent. However, farmers are not informed about the quality and it seems they are not concerned

CHAPTER 6

CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusion Drawn From the Present Study

- 1) Current wastewater effluent from KYWWTP is unsuitable for irrigation due to the higher concentration of EC, TDS and Cl where the average concentration of EC is arranged between (4200-5100) microS/cm, TDS (280)mg/l and Cl (866.7) mg/l .these concentrations are above the permissible limit according to the Palestinian standards. The recovery Wells showed no changes in concentrations of these parameters.
- 2) The BOD₅ and COD concentrations of effluent in KYWWTP are not adequate for irrigation purposes. The average concentration of BOD₅ is 132.5 (mg/l), ,while COD is 364.3 (mg/l), Even though the effluent treated wastewater from the KYWWTP is in accordance with the Palestinian high, SAT treatment added more treatment concerning the BOD₅ is 48.3 mg/l and COD 125.5 mg/l to which is suitable for irrigation without restrictions. Moreover SAT treatment improve the quality of treated effluent by reducing the TSS 129 mg/l to considerable values as a result treated effluent can be supplied to the farm through drip irrigation.
- 3) Current wastewater of KYWWTP could be used for irrigating salt sensitive crops under extended management practices. Management practices, such as applications of soil amendments, periodic leaching to reduce salt accumulation; frequent aerifications to maintain infiltration, percolation, crop rotation, drainage and regular soil and plant monitoring will be helpful in mitigating the negative impact and ensuring continued success in using RWW for irrigation.
- 4) Salt was leached out of the root zone at the early start for the first three years because of sandy soil, and then it accumulates on the top soil layer as its level increases significantly under repeated wastewater irrigation. Even there were problems associated from wastewater reuse, yet it could be managed by different ways including irrigation pattern, nutrients load, soil enhancement and crop selection.
- 5) The wastewater content of NO₃⁻ and NH₄⁺ are an added value to the effluent wastewater. The farmers in the Gaza Strip use huge amount of chemical fertilizers which cost and maximize the input to the farm. By using the treated effluent with high nutrients content will reduce the input of chemical fertilizer. All the samples have NO₃⁻ concentrations above the

permissible limit of the WHO standard indicated that NO_3^- value 33.6 mg/l in recovery wells and NH_4^+ it's noticed that nitrate level of applied wastewater increases with time.

6) Despite of the high level of FC in effluent, there was biological contamination as its FC was in unacceptable range ($>1000\text{CFU}/100\text{ml}$). Moreover that's health risks or outbreaks were encountered along the two year experiment. This means that irrigated water biological contamination must be managed by and controlled, While FC in recovery wells is ranged between (0-57cfu/100ml) that lower than WHO standard which boost the idea of recovery well technique

7) The Effluent quantities from treatment plants meet the required quantities for agriculture irrigation under different scenarios of wastewater reuse plans. Currently most of effluent quantities of GS treatment plants (about 43MCM) are required by current crops to be used for irrigation based on crops areas in GS. This means that treated effluent in winter time should be stored or recharged.

8) Most of farmers would accept using treated wastewater in irrigation, The higher yield were the most relevant reasons for accepting the use of treated wastewater, increasing salinity level in the local agricultural wells and increasing fuel price and maintenance cost.

9) Most of respondent farmers who use wastewater reuse in irrigation are have not willingness to pay for receiving wastewater reuse in irrigation but all of respondent farmers who use wastewater reuse in irrigation are not accepting any compulsory actions to use treated wastewater in irrigation.

10) An economical improvement for farmers switching from groundwater to effluent irrigation, Where (86.4%) of farmers reported no changes of product quality after irrigation by treated wastewater, (90%) of farmers did not observe any change of product quantities, prices and no problems were faced when selling their products in local markets.

6.2 Recommendations

Groundwater is the unique resource for agriculture and drinking demand in Gaza strip. Treated wastewater is seen as one of the promising solutions that can assist Gaza in filling the gap between the growing needs for water and the limited water resources. In order to further spread the irrigation of farmland using treated sewage water, there are some recommendations desirable to be followed:

- 1) Whenever wastewater intended to be used for irrigation, a control unit should be initiated along side with the reuse project for scientific purposes and comparisons.
- 2) Whenever wastewater being used for irrigation in other places in GS more care should be given especially for salinity as it dominates GS aquifer, thus more control measures should be taken as crops selection and leaching fraction.
- 3) More efforts are needed to improve the characteristics of treated wastewater from KYWWTP, especially salinity parameters, BOD₅, TSS and fecal coliform, in order to expand the application of reuse in agriculture.
- 4) It is highly recommended to upgrade the facilities in the temporary KYWWTP and compactly lining the bottom of the lagoons to avoid to any undesirable seepage may harm the aquifer and exert the efforts to improve the quality of effluent to reach the recordable standards which allow slight restricted irrigation for palm, olive, fodder and almond trees.
- 5) It is of great importance to implement long term studies in the areas of the Gaza strip that irrigated by treated wastewater, to find out the most important environmental problems associated with treated wastewater reuse.
- 6) Training the farmers and improving their knowledge about the use of treated wastewater use in agriculture is of great importance to increase their acceptance in using it for irrigation.
- 7) Increasing the quality of treated wastewater to reach a level which allows irrigating annual crops, will improve farmer livelihood. Moreover, it will enable higher coverage of treatment cost.
- 8) The price of treated wastewater should be differentiated based on the purpose of using it, since farmers would pay a much higher price to irrigate their rain fed land. On the other hand, they will not use it to replace fresh water irrigation unless it is much cheaper.

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APPENDIX 1:

PARAMETERS CONCENTRATIONS IN THE INFLUENT&EFFLUENT OF THE KYTTP

BOD₅			
M,Y	BOD (Effluent) (mg/l)	BOD Recovered (mg/l)	Efficiency%
Jan,2011	100	35	65
Feb,2011	70	10	86
Mar,2011	110	15	86
Apr,2011	135	24	82
May,2011	137	15.3	89
June,2011	140	20	86
Jul,2011	140	35.3	75
Aug,2011	125	41.3	67
Sep,2011	130	21.7	83
Oct,2011	95	25.3	73
Nov,2011	110	22.3	80
Dec,2011	30	14.3	52
Jan,2012	110	60.8	45
Feb,2012	120	62.4	48
Mar,2012	160	73.9	54
Apr,2012	155	72.5	53
May,2012	170	77.9	54
June,2012	185	82.6	55
Jul,2012	198	86.6	56
Aug,2012	210	90.3	57
Sep,2012	171	78.7	54
Oct,2012	165	75.4	54
Nov,2012	113	61.6	46
Dec,2012	95	56.2	41
Average	132.2	48.3	64.2
S.D	41.1	27.4	15.5

COD			
M,Y	COD(Effluent) (mg/l)	COD Recovered (mg/l)	Efficiency%
Jan,2011	300	78	74
Feb,2011	220	20	91
Mar,2011	300	43	86
Apr,2011	280	56	80
May,2011	285	36.7	87
June,2011	290	50	83
Jul,2011	300	124.0	59
Aug,2011	220	98.9	55
Sep,2011	320	129.4	60
Oct,2011	380	147.5	61
Nov,2011	400	151.2	62
Dec,2011	140	75.6	46
Jan,2012	220	99.5	55
Feb,2012	380	147.5	61
Mar,2012	390	150.9	61
Apr,2012	514	186.7	64
May,2012	530	191.9	64
June,2012	560	203.4	64
Jul,2012	580	209.7	64
Aug,2012	680	241.7	64
Sep,2012	350	138.4	60
Oct,2012	460	173.2	62
Nov,2012	315	127.0	60
Dec,2012	330	132.1	60
Average	364.3	125.5	65.9
S.D	131.2	59.7	11.4

TSS			
M,Y	TSS (Effluent) (mg/l)	TSS Recovered (mg/l)	Efficiency%
Jan,2011	105	15	86
Feb,2011	100	16	84
Mar,2011	135	16	88
Apr,2011	140	20	86
May,2011	145	20	86
June,2011	130	20	85
Jul,2011	130.0	36.7	72
Aug,2011	117.0	24.0	79
Sep,2011	112.0	26.0	77
Oct,2011	120.0	19.7	84
Nov,2011	100.0	16.7	83
Dec,2011	40.0	14.3	64
Jan,2012	165.0	20.0	88
Feb,2012	150.0	12.3	92
Mar,2012	162.0	18.7	88
Apr,2012	106.0	19.0	82
May,2012	171.0	23.3	86
June,2012	183.0	23.7	87
Jul,2012	152.0	22.3	85
Aug,2012	121.0	17.3	86
Sep,2012	117.0	18.7	84
Oct,2012	131.0	15.3	88
Nov,2012	126.0	14.0	89
Average	128.6	19.5	83.9
S.D	30.1	5.2	6.1

M,Y	pH (Effluent)	pH Recovered
Jan,2011	7.98	7.19
Feb,2011	7.65	7.20
Mar,2011	8.02	7.34
Apr,2011	7.81	7.05
May,2011	7.78	7.16
June,2011	7.69	7.17
Jul,2011	7.73	6.99
Aug,2011	7.75	6.87
Sep,2011	7.75	7.03
Oct,2011	7.6	6.8
Nov,2011	7.78	7.12
Dec,2011	7.75	7.01
Jan,2012	7.7	7.07
Feb,2012	7.6	7.25
Mar,2012	8.4	7.22
Apr,2012	7.796	7.22
May,2012	7.9	7.22
June,2012	7.72	7.23
Jul,2012	7.81	7.20
Aug,2012	7.85	7.20
Sep,2012	7.8	7.03
Oct,2012	7.59	7.07
Nov,2012	7.68	7.03
Dec,2012	7.82	7.04
Average	7.7	7.11
S.D	0.17	0.13

M,Y	EC (Effluent)	EC Recovered
Jan,2011	4470	4567
Feb,2011	4390	4443
Mar,2011	4450	4443
Apr,2011	4690	4573
May,2011	4670	4569
June,2011	4605	4583
Jul,2011	4260	4080
Aug,2011	4480	4293
Sep,2011	4840	4490
Oct,2011	4900	4413
Nov,2011	4500	4343
Dec,2011	4600	4593
Jan,2012	4660	4510
Feb,2012	4610	4190
Mar,2012	5102	4427
Apr,2012	5020	4083
May,2012	5120	4193
June,2012	5080	4000
Jul,2012	5000	4157
Aug,2012	4790	4077
Sep,2012	4720	4003
Oct,2012	5080	4110
Nov,2012	5280	4143
Dec,2012	5170	4173
Average	4770.2	4310.6
S.D	283.5	206.1

M,Y	TDS (Effluent)	TDS Recovered
Jan,2011	2700	2720
Feb,2011	2630	2630
Mar,2011	2670	2663
Apr,2011	2815	2742
May,2011	2850	2730
June,2011	2900	2700
Jul,2011	2560	2450
Aug,2011	2700	2587
Sep,2011	2900	2587
Oct,2011	2940	2638
Nov,2011	2700	2610
Dec,2011	2760	2700
Jan,2012	2790	2703
Feb,2012	2700	2412
Mar,2012	2870	2832
Apr,2012	2910	2450
May,2012	2895	2783
June,2012	2970	2943
Jul,2012	2650	2603
Aug,2012	2855	2833
Sep,2012	2935	2897
Oct,2012	2975	2967
Nov,2012	2820	2760
Dec,2012	2935	2890
Average	2809.5	2701.2
S.D	120.3	149.6

M,Y	FC (Effluent)	FC Recovered
Jan,2011	30000	15
Feb,2011	180000	0
Mar,2011	30000	0
Apr,2011	30000	10
May,2011	400000	0
June,2011	5000000	0
Jul,2011	9000	7
Aug,2011	8000	48
Sep,2011	9000	23
Oct,2011	20000	7
Nov,2011	400000	0
Dec,2011	200000	0
Jan,2012	500000	3
Feb,2012	700000	2
Mar,2012	30000	5
Apr,2012	1000000	3
May,2012	500000	2
June,2012	6000000	2
Jul,2012	10000	9
Aug,2012	9000	57
Sep,2012	8000	42
Oct,2012	30000	17
Nov,2012	300000	7
Dec,2012	350000	6
Average	656375	11.04
S.D	1521732	15.9

M,Y	Cl (Effluent)	Cl Recovered
Jan,2011	870	820
Feb,2011	890	700.0
Mar,2011	915	836.7
Apr,2011	910	843.3
May,2011	980	911.7
June,2011	1010	990.7
Jul,2011	998	910.0
Aug,2011	940	889.3
Sep,2011	910	870.0
Oct,2011	840	800.0
Nov,2011	810	776.7
Dec,2011	800	727.3
Jan,2012	1000	820.0
Feb,2012	1000	833.3
Mar,2012	990	873.3
Apr,2012	1096	868.7
May,2012	990	860.0
June,2012	1120	1016.7
Jul,2012	970	940.0
Aug,2012	935	921.7
Sep,2012	870	850.0
Oct,2012	890	875.3
Nov,2012	910	900.0
Dec,2012	875	823.3
Average	938.2	860.7
S.D	80.3	72.2

M,Y	NO3 (Effluent)	NO3 Recovered
jan,2011	1	15
Feb,2011	1.8	15.00
Mar,2011	0.98	16.30
Apr,2011	1.5	20.00
May,2011	1.2	35.00
June,2011	2.2	26.00
jul,2011	2	30.00
Aug,2011	1	37.00
Sep,2011	1.8	28.66
Oct,2011	1.4	32.00
Nov,2011	2.4	27.66
Dec,2011	1.9	36.66
jan,2012	1	45.00
Feb,2012	1	30.33
Mar,2012	1.2	24.33
Apr,2012	1	18.33
May,2012	1.7	30.67
June,2012	2.3	50.00
jul,2012	3.1	51.67
Aug,2012	2.1	51.00
Sep,2012	2.9	56.00
Oct,2012	3	40.00
Nov,2012	2	46.67
Dec,2012	2.2	43.67
Average	1.8	33.6
S.D	0.7	12.3

M,Y	NH₄(N) Effluent	NH₄(N) Recovered
Jan,2011	75	45.0
Feb,2011	70	49.0
Mar,2011	63	39.3
Apr,2011	60	37.0
May,2011	50	48.0
June,2011	60	55.0
Jul,2011	70	46.0
Aug,2011	66	40.0
Sep,2011	62.5	41.8
Oct,2011	70	55.7
Nov,2011	70	54.0
Dec,2011	57	51.5
Jan,2012	70	28.6
Feb,2012	64	52.0
Mar,2012	68	17.0
Apr,2012	82	43.0
May,2012	56	38.3
June,2012	67	53.3
Jul,2012	72	55.7
Aug,2012	63	48.7
Sep,2012	65.2	52.3
Oct,2012	74	43.3
Nov,2012	72	42.7
Dec,2012	68	54.0
Average	66.4	45.4
S.D	6.9	9.3

APPENDIX 2:

SOCIOECONOMIC QUESTIONNARS OF THE FARMAERS IN AREAS AL MAWASI-KHAN YOUNIS

English Version

Demographic Data

Family..... Name

Education level..... Family size.....

Farm Dependency..... Monthly Income.....

Telephone Number

Agriculture Association Membership

Yes..... No.....

Water Association Membership

Yes..... No.....

Land Resources

Farm Ownership

Ownership..... Sharing.....

Total Area

Water resources

Owns privet wells

Yes No

Wells Type

Shallow Deep

Type Of Water Used

Ground Water.....

Treated Wastewater.....

Wastewater Basins

Yes

No

Training courses

Yes

No

Kind of courses

Theoretical

Practical

No. Of training courses

Health Facilities

Yes

No

Total Area

Quantities Of Wastewater

Economic Consideration

Crop Quality Changes After Irrigated

Yes

No

Product Quantity Changes After Irrigated

Yes

No

Fertilizer Quantity

Arabic Version

البيانات الشخصية/

الاسم:.....
العائلة:.....
عدد أفراد العائلة :
المستوى التعليمي :.....
مستوى الدخل الشهري :
هل هناك عمل آخر للمزارع :
رقم التليفون :
تاريخ المقابلة :

هل لدى المزارع عضوية في جمعية زراعية

☐ نعم ☐ لا

اسم الجمعية مقرها

هل لدى المزارع عضوية في جمعيات مستخدمي المياه

☐ قبل الاستخدام ☐ بعد الاستخدام

المؤشرات الاجتماعية الرئيسية

١.١ ملكية المزرعة ملك ☐ مشاركة ☐ مستأجرة ☐

١.٢ المساحة الكلية للمزرعة

١.٣ أنواع المحاصيل التي يتم زراعتها

نوع الزراعة		المساحة المزروعة	المحصول
مفتوح	مغلق		

٢. مصادر المياه المستخدمة في الري

٢.١ آبار زراعية خاصة

☐

لا

☐

نعم

رقم البئر

نوع البئر المستخدم

كميات المياه المستخدمة

نوع المياه المستخدمة

ملوحة نترات

نوعية المشاركة في البئر

☐

شراء مياه

☐

ملك عام

☐

ملك خاص

عند الشراء : سعر الشراء / متر مكعب/NIS

٢.٢ طريقة ري المحاصيل بمياه الآبار

الري بالغمر ☐ الري بالتنقيط ☐ الري بالرش ☐

٢.٣ المساحة لكل أنواع الري

الري بالغمر	الري بالتنقيط	الري بالرش	
			نوع المحصول
			المساحة الكلية

2.4 استخدام المياه المعالجة في عمليات الري

كمية المياه المستخدمة

نوعية المياه المعالجة

ملوحة نترات

عدد مرات الري

طرق الري

الري بالغمر ☐ الري بالتنقيط ☐ الري بالرش ☐

هل يتم استخدام أحواض مياه عادمة

نعم ☐ لا ☐

عدد العاملين في المزرعة قبل وبعد مشاريع إعادة استخدام المياه العادمة المعالجة:

قبل ☐ بعد ☐

عدد الدورات التدريبية قبل البدء باستخدام المياه العادمة المعالجة في الري

☐

نظري

☐

عملي

نوع التدريب :

هل تلقيت دورات تدريبية حول سبل السلامة في استخدام المياه العادمة المعالجة

☐

لا

☐

نعم

في حالة نعم/ عدد الدورات

☐

نظري

☐

عملي

نوعية الدورات

الدروس المستفادة

وسائل السلامة الموصى بها من الجهات ذات العلاقة (وزارة الزراعة – سلطة المياه)

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لا

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نعم

في حالة نعم: ما هي /

١.

٢.

٣.

٣. التقبل الاجتماعي

٣.١ الاستعداد الاجتماعي لاستخدام المياه العادمة المعالجة

نعم ☐ لا ☐

3.2 الاستعداد لدفع ثمن المياه العادمة المعالجة لاستخدامها في عمليات الري

نعم ☐ لا ☐

في حالة الإجابة بنعم :

سعر المياه المعالجة الممكن دفعه

٣.٣ تقبل شروط إجبارية لاستخدام المياه العادمة المعالجة لري محاصيل زراعية معينة

نعم ☐ لا ☐

٤. المؤشرات الاقتصادية

٤.١ هل يتم بيع المنتجات الزراعية التي يتم ريها بالمياه العادمة المعالجة

محلي ☐ تصدير المنتج ☐

٤.٢ هل هناك أي معوقات في تسويق المنتجات المروية بالمياه العادمة المعالجة

٤.٣ التغيرات التي طرأت على المحاصيل بعد الري بالمياه العادمة المعالجة

☐

لا

☐

نعم

١. من محصول إلى محصول

المساحة من دونم إلى دونم.

٢. من محصول إلى محصول

المساحة من دونم إلى دونم.

٣. من محصول إلى محصول

المساحة من دونم إلى دونم.

٤.٤ التغيرات في كميات الإنتاج: من إلى

٤.٥ التغيرات في أسعار السوق : من إلى

٤.٦ كمية الأسمدة المستخدمة في الري بمياه الآبار..... دونم

نوع المحصول	نوع السماد	كمية السماد (كجم/دونم)	قبل الري بالمياه المعالجة	بعد الري بالمياه المعالجة	ملاحظات
١					
٢					
٣					
٤					
٥					
٦					
٧					

٥. المخاطر الصحية على مستخدمي المياه العادمة المعالجة

٥.١ هل هناك مشاكل في تزويد المزارعين بالمياه العادمة المعالجة وجودتها

١.
٢.
٣.
٤.
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٥.٢ هل هناك حالات مرضية رصدت في المزرعة نتيجة لاستخدام المياه العادمة المعالجة

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نعم

APPENDIX 3:

Environmental Authority new regulations for wastewater reuse standards

2014.

Article (1)

Definitions

In applying the provisions of this resolution, the following words and phrases have the following meanings unless the context indicates otherwise.

Authority	Environmental Quality Authority
The competent Entities	Is any governmental entity has the authority to supervise and operate the sewer and rainwater systems and their facilities such wastewater treatment plants and pumping stations. This entity represented by municipalities, ministries, or on behalf of private sectors.
Wastewater	Water polluted by solid substance, liquid or gas or microorganisms resulted from houses or buildings or various facilities.
Treated wastewater	Effluent water from waste water treatment plant treated in a proper way according to the treated wastewater standards. The standards depend on the purpose of use or disposal unless mixed with water from other sources.
Wastewater Treatment	Is the process of removing physical, chemical and biological contaminants from wastewater and household sewage, domestic, commercial and institutional? Its objective is to produce an environmentally safe fluid suitable for disposal or reuse.
Re-use of treated wastewater	Reuse for wastewater to be used for specific purpose.
Biochemical oxygen demand (BOD ₅)	The amount of dissolved oxygen required for the oxidation of organic matter in sewage by aerobic biological organisms within five days at 20 ° C, and it is expressed in mg per liter.
Chemical Oxygen Demand(COD)	The amount of oxygen required for the oxidation of organic matter that can be oxidizable chemically in wastewater, and is expressed in mg per liter.
Suspended solids (TSS)	Suspended solids in water that can be removed by filtration using a laboratory filter paper size 45 micrometers, and it is expressed in mg per liter.
Contaminant	Any physical, chemical, radiological, organic matter found in the water and leads to lower the water quality and make it dangerous to use.
Limits	The maximum concentration of the contaminant allowed to be in sewage, according to the specified standards and regulation
Green Areas	Areas specified for aesthetic, purposes and coordinating and non-earmarked for the purpose of recreation.
Industrial Crops	Crops that are used for industrial purposes such as timber
Fodder crops	Crops that is grown in order to obtain a total of bio (stems and roots) to be used to animal feed, such as Trefoil, Fodder Corn and other.

Table (1):**Limits and standards for the re-use of treated sewage water for different purposes**

Property Mg/L Unless otherwise stated	Discharge to the sea	recharging the aquifer by filtration	Irrigation of dry feed	Irrigation of green feed	Irrigation of parks and playgrounds	Irrigation of Industrial crops and grains	Irrigation of Forest trees and forests	Irrigation of Citrus trees	Irrigation of olive trees	Irrigation of Almond trees
Biochemical oxygen demand BOD5	40	20	60	45	40	60	60	45	45	45
Chemical oxygen demand COD	100	50	120	90	80	120	120	90	90	90
Dissolved Oxygen DO	More than 1	More than 2	More than 0.5	More than 0.5	More than 0.5	More than 0.5	More than 0.5	More than 0.5	More than 0.5	More than 0.5
Total Dissolved Solids TDS	-	1000	1200	1200	1500	1500	1500	1000	1500	1000
Total Suspended Solids TSS	60	50	50	40	30	50	50	40	40	40
Hydrogenous PH	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9
Color (PCU)	Free	Free	Free	Free	Free	Free	Free	Free	Free	Free
Turbidity (NTU)	-	2	5	5	5	5	5	5	5	5
Fat Oil and Grease	8	0	5	5	5	5	5	5	5	5
Phenol	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Detergents (MBAS)	25	5	15	15	15	15	15	15	15	15
Nitrates NO3	45	30	50	50	50	50	50	50	50	50

Total Nitrogen TKN	50	25	100	100	45	100	100	100	100	100
Phosphate-Phosphorus P-PO4	10	15	30	30	30	30	30	30	30	30
Chlorides CL-	-	350	500	500	500	500	500	400	600	400
Sulphates SO4	300	300	500	500	500	500	500	500	500	500
Sodium Na	200	200	200	200	200	200	200	200	200	200
Magnesium Mg	60	60	60	60	60	60	60	60	60	60
Calcium Ca	200	200	400	400	400	400	400	400	400	400
SAR	6	6	9	9	10	9	9	9	9	9
Aluminium Al	2	2	5	5	5	5	5	5	5	5
Arsenic Ar	0.05	0.05	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Copper Cu	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Iron Fe	5	5	5	5	5	5	5	5	5	5
Manganese Mn	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nickel Ni	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Lead Pb	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Selenium Se	0.02	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Cadmium Cd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zinc Zn	5	5	2	2	2	2	2	2	2	2
Cyanide CN	0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Carbon Cr	0.02	0.05	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Mercury Hg	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cobalt Co	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Boron B	1	1	2	2	2	2	2	2	2	2
Faecal Coliform (CFU /100 ml)	500	200	200	200	200	200	200	200	200	200
E.coli (CFU / 100 ml)	Free	Free	Free	Free	Free	Free	Free	Free	Free	Free
Pathogens	Free	Free	Free	Free	Free	Free	Free	Free	Free	Free
Amoeba and Gardia (Cyst/L)	Free	Free	Free	Free	Free	Free	Free	Free	Free	Free
Nematodes (Eggs/L)	Less than 1	Less than 1	Less than 1	Less than 1	Less than 1	Less than 1	Less than 1	Less than 1	Less than 1	Less than 1

(-): Non specific

Table (2):
Quality control

Property	Frequency of samples	Evaluation period
Microbiological tests - Investigation of colon bacteria and fecal coliform. - Investigation of pathogenic microbes	Sample / two weeks Sample / weeks / summer ** Sample / weeks / Winter ***	3 Months If you receive a positive result for any sample Two additional samples should be taken two days behind them, and if the results of these samples are positive stop the use of water for irrigation until the demise of the pollution.
Biological tests Investigation of intestinal worms and protozoa	Sample / two months	year
Chemical Tests - Routine testing - Tests for the rare elements and heavy	Sample / month Sample / year	Year year

(*)The evaluation period: Period prior to the evaluation phase basis for judging the quality of water is to be taken.

(**) Summer: The period from the beginning of the month of May until the end of the month of October.

(***) Winter: The period from the beginning of the month of November until the end of the month of April.

APPENDIXES 4

FAO Guidelines for interpretation of Water Quality for Irrigation, Ayers and Westcott, 1985

Parameter		Units	Degree of restriction on use		
			None	Slight to moderate	Severe
Salinity EC_w^a		dS/m	<0.7	0.7–3.0	>3.0
TDS		mg/l	<450	450–2000	>2000
TSS		mg/l	<50	50–100	>100
SAR ^b	0–3	meq/l	>0.7 EC_w	0.7–0.2 EC_w	<0.2 EC_w
SAR	3–6	meq/l	>1.2 EC_w	1.2–0.3 EC_w	<0.3 EC_w
SAR	6–12	meq/l	>1.9 EC_w	1.9–0.5 EC_w	<0.5 EC_w
SAR	12–20	meq/l	>2.9 EC_w	2.9–1.3 EC_w	<1.3 EC_w
SAR	20–40	meq/l	>5.0 EC_w	5.0–2.9 EC_w	<2.9 EC_w
Sodium (Na^+)	Sprinkler irrigation	meq/l	<3	>3	
Sodium (Na^+)	Surface irrigation	meq/l	<3	3–9	>9
Chloride (Cl^-)	Sprinkler irrigation	meq/l	<3	>3	
Chloride (Cl^-)	Surface irrigation	meq/l	<4	4–10	>10
Chlorine (Cl_2)	Total residual	mg/l	<1	1–5	>5
Bicarbonate (HCO_3^-)		mg/l	<90	90–500	>500
Boron (B)		mg/l	<0.7	0.7–3.0	>3.0
Hydrogen sulfide (H_2S)		mg/l	<0.5	0.5–2.0	> 2.0
Iron (Fe)	Drip irrigation	mg/l	<0.1	0.1–1.5	>1.5
Manganese (Mn)	Drip irrigation	mg/l	<0.1	0.1–1.5	>1.5
Total nitrogen (TN)		mg/l	<5	5–30	>30
pH			Normal range 6.5–8		

Guidelines for Irrigation Water Quality (FAO, 1992)

Water parameter	Symbol	Unit ¹	
SALINITY			
<u>Salt Content</u>			
Electrical Conductivity	EC _w	dS/m	0 – 3
(or)			
Total Dissolved Solids	TDS	mg/l	0 – 2000
<u>Cations and Anions</u>			
Calcium	Ca ⁺⁺	me/l	0 – 20
Magnesium	Mg ⁺⁺	me/l	0 – 5
Sodium	Na ⁺	me/l	0 – 40
Carbonate	CO ₃ ⁻	me/l	0 – .1
Bicarbonate	HCO ₃ ⁻	me/l	0 – 10
Chloride	Cl ⁻	me/l	0 – 30
Sulphate	SO ₄ ⁻	me/l	0 – 20
<u>NUTRIENTS²</u>			
Nitrate-Nitrogen	NO ₃ -N	mg/l	0 – 10
Ammonium-Nitrogen	NH ₄ -N	mg/l	0 – 5
Phosphate-Phosphorus	PO ₄ -P	mg/l	0 – 2
Potassium	K ⁺	mg/l	0 – 2
<u>MISCELLANEOUS</u>			
Boron	B	mg/l	0 – 2
Acid/Basicity	pH	1–14	6.0 – 8.5
Sodium Adsorption Ratio ³	SAR	(me/l) ^{1, 2}	0 – 15