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Faculty of Graduate Studies

MSc Program in Water and Environmental Engineering

Use of Treated Municipal Wastewater in Irrigated Agriculture in Palestine "Jenin as a Case Study": Driving Forces and Practices

استخدام المياه العادمة البلدية المعالجة في الزراعة المروية في فلسطين "جنين": القوى الدافعة والممارسات

A Master Thesis

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The findings, interpretations, and conclusions expressed in this research do not necessarily reflect the views of Birzeit University, the individual members of the M.Sc. Committee, or their respective employers.

Dedication

To Palestine, the homeland and the human being.

To Palestine, with hope and belief in liberation and freedom.

To my beloved mother ... the bridge of love ascending to heaven, your satisfaction and valleys from the river of contentment.

To my father, the compassionate ... who derives from the tooth of his soul, springs of hope and light of loyalty.

To my brothers and sisters for their continued support.

I dedicate them all the fruit of my scientific harvest.

Asked God Almighty to benefit them

Acknowledgment

Praise be to God, who sent Muhammad, peace and blessings be upon him, as guidance and good tidings. We thank God for the apparent blessings that have come down on us. Thank you, Lord, for what is necessary for the majesty of your face and the greatness of your authority

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May Allah reward them with all the best in us, and guide them to the straight path.

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List of Abbreviations

Abbreviations	Concept
ANERA	The American Near East Refugee Aid
ARIJ	Applied Research Institute – Jerusalem
EPA	Environmental Protection Agency
EQA	Environment Quality Authority – *Palestine*
FAO	Food and Agriculture Organization
FW	Freshwater
ha	Hectare
K	Potassium
MCM	Million Cubic Meter
MENA	Middle Eastern and North African
MoA	Ministry of Agriculture- *Palestine*
N	Nitrogen
P	Phosphorous
PCBS	Palestinian Central Bureau of Statistics
PWA	Palestinian Water Authority
RW	Reclaimed wastewater
SPSS	Statistical Package for Social Science software
SSDI	Sub-surface Drip Irrigation
SDI	Surface Drip Irrigation
S3DI	Shallow Sub-surface Drip Irrigation
TWW	Treated Waste Water
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
WB	West Bank – *Palestine*
WHO	World Health Organization
WTP	Willingness to pay
WUE	Water Use Efficiency
WWTP	Wastewater treatment plant

Abstract

The overall goal of this research was to assess, analyse and document the current status of using treated effluent in irrigation in Palestine, and Jenin City in Particular. Furthermore, the specific goals of the research were to investigate: the driving forces of the farmers' acceptance in Jenin for using treated effluent in irrigated agriculture considering their worries and obstacles, the farmers' knowledge and practices of using treated effluent in irrigation combined with the supervision on these practices and the effects on crop, soil, health, marketing, and technical issues as reported by the farmers' sample. The driving forces included economic aspects, socio-cultural aspects, environmental aspects, and institutional and managerial aspects.

The data collected from the farmers' sample was analysed using Statistical Package for Social Science software, SPSS. Besides, additional interviews were held with experts and official representatives from the municipality, wastewater treatment plant in Jenin, agricultural department, and experts from the American Near East Refugee Aid (ANERA); the founder of the irrigation project in Jenin City in 2014. These interviews were meant to allow for a better understanding of the situation in the city regarding the agricultural reuse of reclaimed water (RW) through various stages of the study, and help establishing the study questions and questionnaire. In addition to the interviews with the farmers' sample and the experts, several laboratory tests of TWW's characteristics were gathered and analysed to in light of the farmers' answers. Size of the sample was determined upon the start of the research to cover the whole community of the farmers who reused RW in their farms. The earlier investigations showed that more than 60 farmers used the treated wastewater (TWW), while the actual number after the elimination process was found to be 44 users due to the reasons explained in Chapter three.

57% of the farmers practiced agriculture as a major career, while 43% of them practiced it as a secondary source of income. And here comes the role of the government who should consider in its future plans to change agricultural and reuse activities into a reliable source of income through providing support and guidance to the agricultural sector. The aggregate cultivated area irrigated with treated effluent reached about 600 dunum, most of which were self-owned farms with an average size of 13.3 dunum each. Almost 60% of the farms were between 10 and 30 dunum in area and were categorized within the medium sized farms. Besides, Three quarters of the farms offered job for less than 5 farmers while the overall number of labors reached 132 with an average of 3 labors per farm. 86.4% of the farmers finished their secondary education, while 34.1% of the farmers got a college degree achieving by that a high educational rate. 29 farmers out of 44 (66%) grew alfalfa crops while 13 out of 44 (30%) grew fruitful trees and

only two of them grew both. The percentage of farmers who didn't use any type of fertilizers reached 59%. However, 16 farmers kept using the same quantity of fertilizers they used to use before turning to the usage of TWW, while the rest of them either reduced or completely stopped fertilizing their crops. Remarkably, none of them has increased the fertilizers quantities in his farm. Regarding irrigation systems, the farmers mainly relied on SSDI for alfalfa, SDI for fruitful trees.

No side effects on animals or men were reported. Five farmers kept irrigating their fruitful trees until the harvest day with the claim that fruits should remain fresh that way. The farmers who adopted the separation strategy were categorized into four categories based on the period; from one to seven days (51.4%), less than two weeks (29.7%), less than three weeks (5.4%), and more than three weeks (13.5%). 3 farmers out of the 13 growing trees didn't hesitate to pick up the falling fruits off the ground and sell them. On the other hand, all the fodder growing farmers abstained from selling their crops before drying it, and 97.7% of the farmers left their products unlabeled as irrigated with TWW.

The 44 interviewed farmers considered the establishing and funding of an irrigation project to be the cornerstone for any reuse project. The second most important driving factor was the price of TWW compared to the fresh water prices. 81.8% and 77.3% of the farmers, respectively, voted for "type of the crop they used to grow in their farms" and "pilot project success" in the third and fourth places as the most essential motivating factors. Availability of fresh water, site of the farm away from the nearest housing areas, and the incentives presented by the government came later in the list of the motivating factors. 31.8 % of the farmers didn't consider the scarcity of fresh water to be severed and claimed that they can still buy it as a resort whenever the quality of the treated water deteriorates significantly.

The main obstacles and worries the farmers faced before entering the field of reuse were; disgust (68.2%), fear of the bad supervision on the treatment process and the quality of the produced water by the labors of the treatment plant (68.2%), fear on their health dealing with a water source that is contaminated with pathogens (63.6%), the worries of the side effects on the soil of their farms (63.6%). One of the farmers stopped using the water after observing some of the side effects on the soil of his land and, according to him; it took him two years of soil rehabilitation to recover from those side effects. Religious worries and the lack of experience came fifth and sixth in the list of obstacles with percentages of (56.8%) and (54.5%), respectively. The factors with the least impact on the farmers' decision regarding their entrance into the reuse business were; the effects on environment, the effects on crop quality, the awareness campaigns that would target the consumers of their products, and marketing.

According to three farmers only, all their worries and concerns were vanished after their experience in dealing with treated wastewater. However, the farmers' mentality was shifted positively regarding the religious and psychological (disgust) worries and negatively in the fields of distrusted water quality claimed to be due to the deficient supervision in the WWTP, the negligence on the part of the government towards the farmers, and the price of treated wastewater. The concerns for marketing and environment were still seen unimportant by the farmers representing the lowest affected aspects amongst all.

The farmers were asked to report their observations of the effects of using the treated wastewater on the following aspects. The positive impacts were noticed highly on the produced quantities (77.3%), crop quality (50.0%), and the marketing of the agricultural products (47.7%). On the other hand, the highest negative impacts were seen on irrigation systems due to pipes' blocking (77.3%), as well as the emission of unpleasant odors (54.5%). The highest contributors to the *"no difference" index* were the impacts on human health (100%), soil quality (56.8%), and the spread of insects (54.5%).

ملخص الدراسة

الهدف العام من هذا البحث هو تقييم وتحليل وتوثيق الوضع الحالي لاستخدام مياه الصرف الصحي البلدية المعالجة في الري في فلسطين ، وبالتحديد مدينة جنين . علاوة على ذلك ، فإن الأهداف المحددة للبحث هي التحقيق في : القوى الدافعة لقبول مزارعي مدينة جنين لاستخدام مياه الصرف المعالجة في الزراعة المروية مع الأخذ بعين الاعتبار مخاوفهم والعقبات المانعة لذلك ، المستوى المعرفي للمزارعين في المجال وممارساتهم مقرونة بالرقابة المفروضة على هذه الممارسات ، والآثار المترتبة على المحاصيل والتربة والصحة والتسويق للمنتجات والمسائل الفنية فيما يخص أنظمة الري . وشملت القوى الدافعة الجوانب الاقتصادية والجوانب الاجتماعية والثقافية والجوانب البيئية والجوانب المؤسسية والإدارية .

تم تحليل البيانات التي تم جمعها من المزارعين الذين تمت مقابلتهم باستخدام برنامج الحزمة الإحصائية للعلوم الاجتماعية SPSS . اهتمت الدراسة كذلك بمقابلة عدد من الخبراء والممثلين لبعض الجهات ذات العلاقة في مدينة جنين كالبلدية ، ومحطة معالجة المياه العادمة ، ومديرية الزراعة وخبراء مؤسسة (ANERA) والتي تعتبر مؤسسة مشروع الري في المدينة في العام 2014 . وكان الغرض من هذه المقابلات الحصول على فهم أفضل فيما يخص تجربة استخدام المياه المعالجة في مجال الزراعة خلال مراحل الدراسة ابتداءا من تحديد أسئلة البحث وتجهيز الاستبيان وانتهاءا بمناقشة النتائج . إلى جانب مقابلة المزارعين والخبراء ، فقد تم جمع عدد من فحوصات المياه المعالجة وتحليلها في ضوء إجابات المزارعين عن الأسئلة المطروحة . ولقد تم تحديد حجم عينة المزارعين في بداية الدراسة وتقرر أن تشمل الدراسة جميع مستعملي المياه المعالجة في ري المزروعات في مدينة جنين . وتبين في المراحل الأولى للدراسة أن عددهم يفوق الستين مزارعا ، حتى تبين لاحقا أن 44 مزارعا فقط هم الذين خاضو تجربة استخدام المياه العادمة المعالجة في الري ، وجاء ذلك نتيجة عدد من الأسباب التي تم التطرق لها في الفصل الثالث .

بينت نتائج الدراسة أن 57% من المزارعين يمارسون الزراعة كمهنة رئيسية ، بينما 43٪ يمارسونها كمصدر ثانوي للدخل ، بلغ إجمالي المساحة المزروعة المروية بالمياه المعالجة حوالي 600 دونم بمعدل 13.3 دونم للمزرعة الواحدة ، معظم المزارع ملكية شخصية وحوالي 60٪ من المزارع تتراوح مساحتها بين 10 و 30 دونم . إلى جانب ذلك ، توفر ثلاثة أرباع المزارع فرص عمل لما يقرب من 5 مزارعين في كل مزرعة ، بينما بلغ العدد الإجمالي للعمال 132 شخص في جميع المزارع . وانهى 86% من المزارعين تعليمهم الثانوي بينما استكمل 34% من المزارعين تعليمهم في الجامعات والمعاهد محققين بذلك نسبة مرتفعة من التحصيل العلمي .

قام 29 مزارعًا من أصل 44 (66٪) بزراعة محاصيل البرسيم بينما قام 13 من 44 (30٪) بزراعة أشجار مثمرة ومزارعان اثنان منهم فقط قاموا بزراعة محاصيل البرسيم والأشجار المثمرة . وبلغت نسبة المزارعين الذين لم يستخدموا أي نوع من أنواع الأسمدة الكيميائية 59٪ وقاموا بالاعتماد فقط على المغذيات الموجودة في المياه المعالجة وتحديدا النيتروجين والفسفور والبوتاسيوم ، ومع ذلك ، استمر 16 مزارعًا في استخدام نفس الكمية من الأسمدة الكيميائية التي اعتادوا استخدامها قبل أن يتحولوا إلى استخدام مياه الصرف الصحي المعالجة في مزارعهم ، بينما قلل الباقون أو توقفوا تمامًا عن تسميد محاصيلهم ، واعتمد المزارعون في الري على نظام الري بالتنقيط تحت التربة في حال زراعة الأعلاف وفوق سطح التربة في حال زراعة الأشجار المثمرة.

لم يتم الإبلاغ عن أي آثار صحية على الحيوانات أو الانسان نتيجة إعادة استخدام المياه المعالجة ، وقد أفاد بعض المزارعين (12%) انهم يستمرون في ري أشجارهم المثمرة حتى يوم الحصاد بدعوى أن الفاكهة يجب أن تبقى طازجة على هذا النحو، وتم تصنيف المزارعين الذين تبنوا استراتيجية التوقف عن استخدام المياه المعالجة قبل موعد قطف الثمار إلى أربع فئات على أساس الفترة الزمنية ؛ من يوم إلى سبعة أيام (51.4٪) وأقل من أسبوعين (29.7٪) وأقل من ثلاثة أسابيع (5.4٪) وأكثر من ثلاثة أسابيع (13.5٪) . 3 مزارعين من أصل 13 مزارعا يقومون بالتقاط الثمار المتساقطة عن الأرض وبيعها، من ناحية أخرى ، امتنع جميع مزارعي العلف عن بيع محصولهم قبل تجفيفه.

يستخدم المزارعون مياه الصرف المعالجة من 5 إلى 9 أشهر سنويًا، ويقوم مزارع واحد فقط من مستخدمي المياه المعالجة بوضع ملصق يبين أن منتجه قد تم رَيّه بمياه عادمة معالجة، بينما 98٪ من المزارعين يقومون بتسويق محاصيلهم دون أي ملصقات تشير إلى أن محاصيلهم تروى بالمياه المعالجة، غير أن جميع مزارعي العلف أكدوا أن لدى عملائهم معرفة سابقة بأنهم يشترون علفاً مروياً بالمياه المعالجة.
وأفاد جميع المزارعين الذين تم مقابلتهم أن إنشاء وتمويل مشروع إعادة استخدام يشكل حجر الزاوية لأي مشروع إعادة استخدام ، وكان ثاني أهم العوامل المحفزة هو سعر المياه المعالجة مقارنة بأسعار المياه العذبة ، وصُنّت لـ "نوع المحصول الذي اعتادوا زراعته في مزارعهم" و "نجاح المشروع التجريبي" في المرتبة الثالثة والرابعة باعتبارهما من أهم العوامل المحفزة كما افاد 81.8٪ و 77.3٪ من المزارعين على التوالي . توافر المياه العذبة ، وموقع المزرعة بعيدًا عن أقرب لمنطقة السكنية ، والحوافز التي قدمتها الحكومة جاءت لاحقًا في قائمة العوامل المحفزة . 31.8٪ من المزارعين لم يعتبروا ندرة المياه العذبة أمرا خطيرا حيث لا يزال بإمكانهم شراء الماء العذب كلما قلت جودة المياه المعالجة بشكل ملحوظ.

كانت أهم المعوقات والمخاوف التي واجهها المزارعون قبل دخولهم مجال إعادة الاستخدام هي : المخاوف النفسية (68.2٪) ، الخوف من سوء الإشراف على عملية المعالجة ونوعية المياه المنتجة من قبل المراقبين في محطة المعالجة (68.2٪) ، الخوف على صحتهم من التعامل مع مصدر مياه قد يحتوي على مسببات الأمراض (63.6٪) ، القلق من الآثار الجانبية على تربة مزارعهم (63.6٪) . أفاد أحد المزارعين توقفه عن استخدام المياه المعالجة بعد ملاحظته بعض الآثار الجانبية على تربة أرضه وزعم استغراق الأمر عامين من إعادة تأهيل التربة للتعافي من تلك الآثار الجانبية ، وجاءت التخوفات الدينية وقلة الخبرة في المرتبة الخامسة والسادسة في قائمة المعوقات بنسب بلغت (56.8٪) و (54.5٪) على التوالي . وكانت العوامل ذات التأثير الأقل على قرار المزارعين استخدام المياه المعالجة على النحو الآتي: التأثيرات على البيئة ، والتأثيرات على جودة المحاصيل ، وحملات التوعية التي تستهدف المستهلكين لمنتجاتهم ، والتسويق .

بعد تجربتهم استخدام مياه الصرف الصحي المعالجة ، تلاشت التخوفات لدى ثلاثة مزارعين على حد قولهم ، ومع ذلك ، فقد تحولت أفكار المزارعين بشكل إيجابي فيما يتعلق بالمخاوف الدينية والنفسية وسلبيًا في مجالات جودة المياه المشكوك فيها التي يعتقد المزارعون أنها ناتجة عن ضعف الإشراف في محطة معالجة مياه الصرف الصحي ، وعدم الاهتمام الكافي من جانب الحكومة، وكذلك سعر مياه الصرف الصحي المعالجة التي اعتبرت مرتفعة ، ولا تزال المخاوف المتعلقة بالتسويق والبيئة قليلة من قبل المزارعين.

وبخصوص ملاحظات المزارعين حول آثار استخدام المياه العادمة المعالجة ، فقد لوحظت الآثار الإيجابية بشكل كبير على الكميات المنتجة (77.3٪) ، وجودة المحاصيل (50.0٪) ، وتسويق المنتجات الزراعية

(47.7٪) وخصوصا المنتجات العلفية . ومن ناحية أخرى ، لوحظت أعلى التأثيرات السلبية على أنظمة الري وانسداد الأنابيب (77.3٪) ، وكذلك انبعاث الروائح الكريهة (54.5٪) . وبخصوص مؤشرات "لا تأثير" كانت النتائج على صحة الإنسان (100٪) ، وجودة التربة (56.8٪) ، وانتشار الحشرات (54.5٪) .

Chapter One

Introduction

1.1 Background

Water is the basis of life on the surface of the earth and an important wealth of necessary resources, and it is the main source that determines the life of humans, animals and plants. The importance of water has increased day by day because of its large, influential and effective role in agricultural development projects in all countries of the world, not to mention that it is considered one of the main pillars for achieving economic, human, industrial and agricultural life and food security goals. Given the importance of the agricultural value of water in the Arab countries, especially since the Arab agricultural sectors are currently exploiting about 80% of the total water consumption, it is noted that the agricultural sector consumes water at a greater rate than the other sectors in general. However, those huge quantities of water used in agriculture are not well utilized by farmers due to the wasteful use of water. And therefore, agricultural policies and guidelines which are based on actual, accurate studies and researches are set and followed to well manage water resources.

The greater the population, the greater the demand for food production, and consequently the greater the demand for water. Since ancient times, man has known the importance of water. Since ancient times, man has used river water, rain water and groundwater, but he did not turn towards the use of treated sewage water. The concepts of collecting and treating sewage are considered relatively modern, let alone the concept of reusing this type of water. After the construction of sanitation networks, the issue of wastewater safe disposal was raised. Later on, the treated wastewater was seen as a valuable water resource for various uses particularly in the arid and semi-arid countries, such as the countries of the Middle East including Palestine.

Treated wastewater is now considered a sustainable source of irrigation water for agriculture and can be used to solve the imbalance between water demand and supply. It is importance is not only in meeting the water needs of crops, but also in encouraging soil microorganisms by increasing the load of organic matter as well as the nutrients content which improve with good control the ratios of soil composing matter (Kayikcioglu, 2018). Treated wastewater is rich of nitrogen, phosphorous and potassium (N,P,K) which are called the major nutrients required for the growth of plants and key factors for crop yield. The indirect benefits of using the treated wastewater in agriculture goes further due to the release of huge amount of fresh water currently used for irrigation, to meet the rising needs of fresh water for drinking and other non-agricultural purposes in villages and cities in developing countries. Besides, the well supervised wastewater reuse is one of the safest and less expensive options of wastewater disposal to the environment.

There are many previous studies that have been addressed and applications about treated wastewater and the extent to which society accepts it, and the effects of reusing it from many aspects, such as: social, economic, religious, and cultural aspects. The results of those studies were summarized by the existence of a water gap between supply and demand as the main problem that should be addressed, whether at the level of the Arab world or Palestine. Many alternatives have been proposed to reduce this gap, the most important of which is the reuse of treated wastewater in agricultural production. Irrigation projects with treated effluents were funded and constructed. This water was applied on different species of plants and the experience in this field was built based on trial and error. Weather, soil, and the composition of irrigation water are determining factors for specifying plants' species adaptation in terms of growth and yield. When a success is recorded for particular specie of crop or plant in some region, the farmers of that region will be motivated to start planting the plant or the crop to achieve the expected profits. In Palestine, this experience was apparent in the city of Jenin, and this is reason why the case study is maid on the irrigation project by the American Near East Refugee Aid (ANERA) in Jenin City.

1.2 Objectives

The overall goal of this research is to assess, analyse and document the current status of using treated effluent in irrigation in Palestine, Jenin City as a case study. Furthermore, the specific goals of the research are:

1. to investigate the driving forces that led to farmers' acceptance of using treated effluent for crops irrigation in the city of Jenin. The driving forces included economic aspects, socio-cultural aspects, environmental aspects, and institutional and managerial aspects.
2. to investigate the farmers knowledge and practices in using treated effluent in irrigation as well as supervision and effects on crop, soil, health, marketing, and technical issues.

1.3 Problem Statement

Over the last few years, the reuse of treated wastewater has been blooming at a faster pace than ever expected in Palestine, mainly in Jenin City in the West Bank. Concerns were always raised about religious beliefs and worries of customers' acceptance of buying products irrigated with treated effluent. The reasons underlying the unexpected success of reusing treated effluent in Jenin City have not been investigated yet, neither the practices has been evaluated nor documented.

1.4 Research Questions

The first crucial step in any research is to specify the research questions. This step is necessary to determine the type of data which is required and the best fitting way for collecting and analysing it. There are major and minor questions to be addressed (answered) in this research. Altogether, six questions were determined to be studied in this research and they are:

1. What are the driving forces that led to the Palestinian farmers' acceptance of municipal treated wastewater for irrigation in the city of Jenin as well as the obstacles, worries, and concerns they had?
2. What are the common practices performed by the farmers involved in the treated wastewater reuse?
3. What is the level of knowledge the farmers have with regard to using treated effluent for irrigation?
4. What are the noticed effects of reusing treaded effluents in terms of quality and quantity of crops? Besides, what are the effects concerning the environmental, technical, marketing and health aspects?
5. What is the future vision according to the farmers and the Ministry of Agriculture (MoA) concerning the agricultural reuse of treated effluents and what are the recommendations for future development?

1.5 Significance

Elucidating the driving forces underlying the farmers' acceptance of using treated effluent will support the policy makers to replicate the success story in other parts of Palestine and the world, especially in the Arabic and Islamic states. Analysing the current practices of using treated effluent will enable fine-tuning the practices from environmental and safety aspects, that is envisaged to enhance the sustainable application of treated effluent use in Palestine and other parts of the world.

Chapter Two

Literature Review

2.1 Overview

Morugán-Coronado *et al*. (2011) considered that the water shortage issue the most important environmental problem in the Mediterranean countries, which is exacerbating along with its negative impacts due to the continuous increase of population. Meanwhile, the demand on food is increasing and leading to food insecurity as well as an increasing production of wastewater. Since Palestinian territories suffer from water shortage and water scarcity, this encouraged an exploration for finding alternative water resources. TWW is considered an alternative water resource for irrigation that naturally help alleviating water shortage (Capra and Scicobone, 2004; Elmeddahi *et al*., 2016; Nassar, 2019). TWW reuse is one of the common practices in Mediterranean countries (Pedrero *et al*., 2010), arid, and semi-arid areas (Nassar, 2019).

Irrigation plays a vital role in increasing crop yield, which is an essential factor for agricultural feasibility (Nassar, 2019). Reuse of TWW in irrigation is found in many countries (USEPA, 1992; Toze, 2006; Pedrero *et al*., 2010; Belaid *et al*., 2012; Lal *et al*., 2015; Schacht *et al*., 2016; Nassar, 2019) Such as in the Mediterranean regions which have been increasing the reuse over the last decades to cope with water shortage and the uneven precipitations which can be referred to climate change (Lonigro *et al*., 2015; Nassar, 2019). Mizyed (2013) stated that the reuse of TWW is still limited to agricultural and industrial purposes due to various economic and social factors. TWW is a considerable source for many purposes (Moghadam *et al*., 2015; Bardhan *et al*., 2016) including irrigation (Balkhair *et al*., 2014; Elmeddahi *et al*., 2016) due to its rich content of nutrients such as N & P as well as soil organic matter which enhances the growth of plants (Babayan *et al*., 2012; Nassar, 2019). In addition to increasing crop productivity (Mohammad and Ayadi, 2004; Hassanli *et al*., 2009; Alkhamisi *et al*., 2011; Khan *et al*., 2012; Minhas *et al*., 2015) and increasing the concentration of N, absorbable P and absorbable K in the soil (Kaboosi, 2016), irrigating with TWW also saves fresh water resources and moderates the wastewater's disposal to the environment (Pedrero *et al*., 2010; Urbano *et al*., 2017; Nassar, 2019).

Due to the difficult situation of agricultural water, the irrigated agricultural land represented around 19% of the total agricultural area in Palestine compared with 37% in Jordan. As in other countries agriculture in Palestine is the major sector of water use, which was reported to be 45% of the total water consumption. Even though, this share of water for irrigation is not enough for meeting the irrigation water demand, which represent the main restriction factor for developing the Palestinian agricultural sector. Therefore, the fluctuation of agricultural sector has been attributed to the fluctuation of the water availability that has a negative impact on the agricultural production (MoA, 2017; Nassar, 2019).

An application of treated wastewater for irrigation is widely accepted in many countries in the world, as this provides additional water source for irrigation. Also, reusing treated effluents is an economical method, for disposal of treated effluent. Although treated wastewater has been used in agriculture in many parts of the world, its acceptability varies with different cultures and beliefs among farmers. Farmers' concerns on treated effluent use are primarily due to psychological and social concerns (a general perception of sewage being dirty, and its offensive odor), potential health risks (pollutants that it carries), and their religious beliefs (its anthropogenic origin), and economic reasons (concerns that the customers are not willing to buy products irrigated with treated effluent) (Rashid *et al.*, 2017).

Palestinian national climate change adaptation plan has considered treated wastewater as one of the agricultural water resources (EQA, 2016; Nassar, 2019) and the Palestinian government has been pushing towards increasing the reuse of TWW in irrigation and other purposes in the last few years (PWA, 2014; Nassar, 2019). The Palestinian Standards of TWW reuse, stated by PWA (2010), complies with the aims and national visions of the Palestinian Policy especially the vision of the PWA that assures the concept of equitable and sustainable management and development of the Palestinian water resources (Adilah, 2010).

2.2 Brief History

Even though wastewater reuse is an ancient practice, it has not always met safe quality standards, and the knowledge related to wastewater reuse in agriculture has evolved through the history of mankind (Angelakis and Snyder, 2015; Jaramillo and Restrepo, 2017). The first evidence of wastewater reuse in history was found in the Greek civilization (Tzanakakis *et al*., 2007; Jaramillo and Restrepo, 2017). Romans and Greeks transported wastewater to the fields and used it as fertilizer for crops and orchards (Cooper, 2001; Jaramillo and Restrepo, 2017).

In the 16th century, the direct use of wastewater on agricultural farms was practiced in Germany, Scotland and England (Drechsel *et al*., 2010; Tzanakakis *et al*., 2014; Jaramillo and

Restrepo, 2017). In the early 19th century, soil irrigation with wastewater was adopted and considered legal in cities like London, Paris and Boston as a treatment and disposal solution to deal with large quantities of wastewater (Felizatto, 2001; Tzanakakis *et al*., 2007; Jaramillo and Restrepo, 2017). In Melbourne, the first field to be irrigated with wastewater was established in 1897 (Tzanakakis *et al*., 2014; Jaramillo and Restrepo, 2017).

The direct use of untreated wastewater in irrigation in open fields caused spreading waterborne diseases such as cholera and typhoid fever (Felizatto, 2001; Jaramillo and Restrepo, 2017). Several milestones in sanitation followed these disasters, such as Great Britain's Public Health Act and their main principal was to discharge wastewater into the soil unlike rainwater to the river (Segui, 2004; Jaramillo and Restrepo, 2017). Besides, led by the European powers, a series of conferences on hygiene and demography were held internationally and the International Office of Public Hygiene was established to control sanitary along borders (Barona and Mestre, 2008; Jaramillo and Restrepo, 2017).

In the beginning, treated wastewater reuse was mainly adopted by European cities and the United States. However, during the 1990s, the practice increased in many parts of the world due to the high water demands in the agricultural sector (Brega Filho and Mancuso, 2003; Asano and Levine, 1996; Jiménez and Asano, 2008; Jaramillo and Restrepo, 2017). As the world started adopting reuse of treated wastewater, global concerns of the associated risks to public health and environment arose, and for the first time in 1973, the World Health Organization (WHO) published a guideline to deal with wastewater and excreta; "Reuse of effluents: methods of wastewater treatment and health safeguards". This guideline did not consider any epidemiological studies and it only followed the minimum risk approach (Carr, 2005; Jaramillo and Restrepo, 2017).

An analysis of all available epidemiological studies was later performed and in 1989 the guideline was updated. Moreover, risk assessment and tolerable risks were considered to determine the suitable limits and standards in each society based on the present situation of a particular disease in a country (Carr, 2005; Jaramillo and Restrepo, 2017). The guidelines were prepared based on health protection measures (Kamizoulis, 2008; Mara *et al*., 2007; Jaramillo and Restrepo, 2017) and no surveillance guidelines were included (WHO, 1989).

The WHO's 2006 guidelines came more descriptive to help governments establishing their own guidelines and regulations for the safe use and management of wastewater based on specific aspects for each country (Mara *et al*., 2007; Mara and Kramer, 2008; WHO, 2006;

Jaramillo and Restrepo, 2017). Besides, in 1987, the quality guidelines of wastewater for agricultural use were developed by the Food and Agricultural Organization of the United Nations (FAO). In 1999, classified on the basis of the type of the irrigated crop, the FAO published the suggested guidelines of the type of agricultural reuse "agricultural reuse of treated waters and treatment requirements" (FAO, 2017).

On the other hand, the Environmental Protection Agency (EPA) has confirmed, in 1992, the toxic effects on crops caused by certain trace elements present in the wastewater used for irrigation (Jaramillo and Restrepo, 2017). In 2004, the EPA expanded the scope and more subjects related to wastewater were addressed. Later in 2012, the guidelines provided by the EPA and United States Agency for International Development (USAID) were updated to facilitate the development of reuse projects based on global experience. The guidelines provided by the WHO, FAO and EPA became the basis for formulation of the regulations in many countries around the world (Jaramillo and Restrepo, 2017). Between 2000 and 2006, 3300 wastewater facilities and more were registered using the framework of the AQUAREC international project around the world. The treated wastewater was used for several purposes but basically for irrigation. Japan and the USA with 1800 and 800 reuse facilities, respectively, were in the lead. Australia and the European Union followed with 450 and 230, respectively. About 100 treatment facilities were recognized in the Mediterranean and Middle East regions, 50 in Latin America and 20 in Sub-Saharan Africa (Wintgens *et al*., 2006; Jaramillo and Restrepo, 2017).

2.3 What Drives Communities' Decisions and Behaviors in the Reuse of Wastewater

Apparently, communities support the idea of reusing treated wastewater as a water resource management option. However, when it comes to actually using it, different reactions are anticipated from people of different communities (Nancarrow *et al*., 2008). Nancarrow *et al*. (2008) managed to develop a systematic model after five years of investigations that predicts the intended behaviour of a certain community towards the reuse of treated wastewater. The study had a great importance since at the time it was published; little has been known on how people make accepting or rejecting decisions. The experiment, Nancarrow *et al*. (2008) performed, relied on direct tasting or swallowing recycled water from different sources and products grown with treated wastewater, and the model was applied on three case studies.

The first planned use of recycled water refers back to the late 1950s. Twenty years later, mostly in the USA, researches concerning public perceptions and acceptance were performed for the first time ever, and were limited to increasing public acceptance using incentives and other applied behavioural methods. Nancarrow *et al*. (2008) stated that the principle obstacle in the early approach of implementing water reuse projects was public acceptance, and thus, researchers only focused on finding ways to convince people to accept the recycled water. Nowadays, social marketing and persuasion are considered ineffective, yet public acceptance of the recycled water is still the main challenge that matters when reuse projects are implemented (Nancarrow *et al*., 2008).

The general look towards recycling water can suddenly change in any community from opposing to considering with the rapid population growth, frequent droughts, or climate change. Until recent years, social researches related to water reuse never took place in Australia for example. Australians started to seriously consider recycling water due to the recent climate change and current drought, especially concerning indirect potable reuse of wastewater. Numerous reuse projects, which were initially supported by the potential users, have failed around the world in the past. Despite being very accepting to the idea of water reuse (Recycled Water Task Force, 2003), Californians have refused the implementation of several water reuse projects (Nancarrow *et al*., 2008).

Communities often show understanding to the need for water recycling but feel that they themselves cannot use the water. Nancarrow *et al*. (2008) reported that ***the yuck factor*** "a barrier to water reuse", or ***disgust*** as a psychological term, has been cited in literature since the 1970s, but no studies on the influence this factor exerts on people behaviour towards water reuse have been conducted. It is anticipated from long-term research that the closer the recycled water is to human contact, the more they are opposed to using it (Bruvold, 1988; D'Angelo Report, 1998; Australian Research Centre for Water in Society (ARCWIS), 2002). Nancarrow *et al*. (2008) built their model to measure the intended behaviour based on the following factors; emotion "yuck factor", attitude, subjective norms, risk perceptions, perceived control, knowledge, trust, responsibility, and environmental obligation (Nancarrow *et al*., 2008).

2.4 FAO Position from TWW Reuse

The Food and Agriculture Organization of the United Nations (FAO) has stated that wastewater, if properly managed, can be safely used to support crop production either directly through irrigation or indirectly by recharging groundwater. But this requires diligent management of health risks, through appropriate treatment or use of water, according to a press release issued by the FAO (World Bank, 2020).

The ways that countries are resorting to address this challenge and the latest trends in the use of wastewater in agricultural production were the focus of discussions held by a group of experts in Berlin during the Global Forum on Food and Agriculture, organized by FAO and with the participation of UNESCO, the World Health Organization and the World Bank (World Bank, 2020).

Commenting on the forum, M. de Sousa, a senior FAO Land and Water Administration official, said, “Although there is a lack of detailed data on this practice, we can say that only a small percentage of treated wastewater is used, mostly municipal wastewater, in the global agricultural sector. However, an increasing number of countries, such as Egypt, Jordan, Mexico, Spain and the United States, are exploring these possibilities as they suffer from water scarcity.” (World Bank, 2020).

Besides helping to cope with water scarcity, wastewater often carries a high nutritional value, making it a good fertilizer. "When wastewater is used and managed safely to avoid health and environmental risks, it can be transformed from a burden to a beneficial resource," de Sousa said (World Bank, 2020).

2.5 Guidelines and Regulations for Wastewater Reuse

The effluent standards vary from country to another, since some countries followed the philosophy of minimizing any risk and as such have developed standards similar to the California’s Title 22 effluent reuse criteria. While the approach of other countries of following the world health organization WHO guidelines of the 1989 is essentially a reasonable expectation of bad effects resulting in the adoption of a set of water quality (Mogheir *et al*., 2007; Adilah, 2010).

2.5.1 WHO Guidelines

The WHO has developed their guidelines in the year 1989 to assist the policy makers to legislate permission for the safe use of wastewater. The previous health standards were not high and did not reflect the situation in developing countries. The recommended quality standards were based on best practice guidelines in order to well manage the reuse (Kramer *et al*., 2007; Adilah, 2010). WHO has always revised their guidelines; the joint FAO, UNEP and WHO publication of Health Guidelines for the Safe Use of Wastewater, Excreta and Greywater has been updated in 2006, focusing on disease prevention and public health principles (WHO, 2006; Adilah, 2010).

2.5.2 EPA Guidelines

In 1992, the USEPA established water reuse guidelines and a comprehensive technical document, including a brief of state reuse requirements, guidelines for wastewater treatment and reuse, key issues in assessing wastewater reuse opportunities, and case studies demonstrating the legal issues, like water rights pertained to treated effluent reuse. Later in the year 2004, updated guiding document of the 1992 guidelines was published including new information on effluent reuse obtained after the 1992 (EPA, 2004; Adilah, 2010).

2.6 Importance of Reusing Treated Wastewater in the Arab Region

The book (Financial Policies and Their Repercussions in the Arab Water Crisis, 2012) presents the water reality in the Arab world, the problems it faces, the future need for water resources in the Arab world, the conflict and ambitions faced by these resources, the strategy of Arab policy in light of water challenges, and among the most important things it dealt with were the studies indicators about water. For example, the global per capita share of water decreased by 5300 m^3 during 25 years (1970 - 1996), or 41%, and the Arab per capita share of available renewable water resources decreased by 50% (from 2200 to 1100 m^3) during the same period.

At the time, it was forecasted that the per capita share would be, in the best cases, 950 m^3 in 2000, and 500 m^3 in 2025 as an average for the Arab world. Statistics also indicated that the percentage of the population that did not have access to potable water at the level of the Arab world was 30% of the total population, which resulted in negative health effects. The Arab world also imported agricultural foodstuffs from abroad with an annual value of about 20%, due to the lack of available water to be used in irrigated agriculture. The researchers also indicated that the water deficit was expected to rise from 62 billion m^3 / year in 2010, to 280 billion m^3 / year in 2030.

Therefore, the book dealt with a study entitled “Available Water Resources and the Actual Future Needs in the Arab Region”, presented by the Egyptian doctor S. Mukhaimer, specializing in water desalination technology. The study included the alternatives offered to overcome the current water gap between supply and demand, namely:

1. Rationalizing the consumption of available resources.
2. Development of available water resources.
3. Adding new water resources.

The latter can be achieved through two axes: adding traditional water resources such as surface water and groundwater, and adding non-conventional water resources by exploiting sewage and desalinated water. As for wastewater, it can be treated with modern techniques and reused in agriculture and industry, under certain conditions and controls, instead of not treating it, which causes serious environmental problems. Besides, from the statistics mentioned also were that 6.4 billion m^3 of TWW amounted to sewage, agricultural and industrial water in the Arab world.

The study of Al-Khatib (2006), entitled (Water Pollution: Sources, Causes, Types of Water Pollution), discussed the quantity and quality of water on Earth. In his study, Al-Khatib (2006) stated that the volume of water in the globe is about 1385 billion km^3, covering about three quarters of the globe represented by: The oceans, seas, rivers and lakes. Most of this water is saline water, accounting for about 97.47% of the total water, while the percentage of fresh water is only 0.9103% of the total water. Thus, one of the most important things that work to protect water from pollution is the treatment and use of sewage water.

In the irrigation of crops or gardens and hydroponic farms, the quality of treated water used for agricultural purposes plays a large role in the soil system and the hydroponic system. The appropriate method for treating irrigation water is the method that ensures suitable quality for the use of agriculture at a low cost. Besides, the use of a low treatment level is what is best for developing countries not only in terms of costs, but in terms of operating the processing system efficiently.

The book Water for the Future (2003) (Committee on Sustainable Water Resources in the Middle East) in the West Bank and Gaza Strip, "Israel", and Jordan presents measures to rationalize water consumption in agriculture, including saving more water by switching to using treated wastewater, and switching from growing crops that require a lot of water to those that require little of it. As for treated wastewater, it was found that reusing it in the study area worked to provide twice the amount of water that can be found through new fresh water sources. The book also confirmed that water is a most valuable element since it is used once and then dispensed with. So, 53% of the total water used in homes in the study area received some kind of treatment and was used for non-drinking purposes based on the quality of the water that was obtained, and the result is that the treated water is economically viable compared to alternative sources, regardless of the degree of treatment.

Trondalen (2008) in his book (Water and Peace for People) presented different ways of thinking about the water conflict between Israelis and Palestinians by suggesting specific steps to be taken. Both sides agreed that water resources were deteriorating due to several realms: growth Population rise, the standard of living and consequently the high demand for water, global climatic changes, and the deterioration of water quality. It also showed that more than 70% of the water basins in the Gaza Strip were polluted or saline, leaving no more than 25% of the water basins fit for drinking.

60% of the diseases recorded in the Gaza Strip were caused by water, and the writer tried to suggest a method of cumulative steps, a method that makes the positions of both parties compatible with each other so that the declared goals of both "Israel" and the Palestinian Authority are achieved; where he presented the sources derived from this method and the steps for its implementation. And in the end, he expected the Palestinians and Israelis to agree on the principles contained in the proposal, but the different questions from both sides would appear, and one of the most important results he reached was that the longer the delay in reaching an agreement, the more it increases the suffering of ordinary people and then it becomes difficult to reach compromises and find a decisive solution (Trondalen, 2008).

2.7 Challenges to Treated Wastewater Reuse in Arid and Semi-arid, West Bank

Middle Eastern and North African (MENA) countries are located within arid and semi-arid areas where availability of fresh water resources is relatively low (World Bank, 2012; Mizyed, 2013). Since the mid of 1940s, the use of treated wastewater (TWW) for irrigation was increasingly paid attention to (Westcot, 1997), and it is continuing to be relied on to satisfy increasing agricultural demands (Mizyed, 2013). Many countries, including Jordan and Tunisia, has implemented the reuse of TWW to irrigate different crops and has been increasingly including it in the planning and development of water resources (Batarseh *et al*., 2011; El Ayni *et al*., 2011; Mizyed, 2013).

In addition to augmenting agricultural water supplies, reuse of TWW allows savings in plant nutrients (Martı´nez *et al*., 2012; Mizyed, 2013). However, TWW reuse has implications on the groundwater in the shape of potential contamination with fecal coliforms and parasite ova (Abd El Lateef *et al*., 2006; Mizyed, 2013). Qadir *et al*. (2010) highlighted the constraints of TWW reuse as follows:

- inadequate information about reuse,
- incomplete economic analyses of wastewater treatment and reuse options,
- high cost of wastewater collection and treatment,
- lack of cost-recovery mechanisms,
- mismatch between water pricing and water scarcity,
- preference of fresh water to wastewater, and
- inefficient irrigation and water management schemes.

Mizyed (2013) stated that there are many challenges to utilizing wastewater in agriculture even in arid and semi-arid areas, where it is considered to be a strategic option, and these challenges are mainly technical, legal, social and economic. Legal challenges go around adopting standards of reuse that should be relevant and appropriate. But mainly, social and economic challenges are the ones to be considered in developing strategies and options of reuse. Treated wastewater reuse standards and guidelines have been adopted in the West Bank. Through field surveys and interviews, Mizyed (2013) ensured that farmers were willing to utilize wastewater for the irrigation of many crops. However, the farmers' willing was not the same of what is recommended by planners and policy makers. In the same context, farmers indicated a good understanding of the technical solutions on the implementation of technically sound and safe treated reuse (Mizyed, 2013).

Besides to the farmers understanding of the technical side of reuse, Mizyed (2013) emphasized that social and economic aspects are also essential for the success of reuse. According to Mizyed (2013), farmers lacked the knowledge of ***"economic costs, returns and benefits of the different qualities of treated wastewater (TWW)"*** in order to select appropriate reuse alternatives. Mizyed (2013) recommended two important steps for the sustainability of treated wastewater reuse; public awareness campaigns to address legal, social, economic and institutional considerations of the reuse, and allowing farmers to participate in developing guidelines, standards, policies and plans for agricultural reuse. Regulations should encourage the utilization of treated wastewater to enhance water supply for agriculture, improve food safety and reduce poverty in agricultural and rural communities. At the same time, these regulations should protect public health, allow safe reuse and take local cultural and socio economic conditions into consideration (Mizyed, 2013).

2.8 Willingness of Farmers to Pay for Reclaimed Wastewater in Jordan, Tunisia and Crete

Despite water scarcity in the Middle East and North Africa region (MENA) and the huge need for agricultural water, which accounts for 87% of total water consumption in the region, Abu Madi *et al*. (2003) stated that treated wastewater was discharged into seas in substantial amounts instead of being reused. Reclaimed wastewater (RW) was rarely recognized by planners as a potential resource in the eighties (Bahri and Brissaud, 1996; Mills and Asano, 1996; Abu Madi *et al*., 2003). According to Abu Madi *et al*. (2003), three factors controlled the market behaviour towards RW; (a) availability of agricultural land, (b) availability of infrastructure for distribution of the treated effluents, and (c) availability of farmers willing to use and pay for RW. Rather than the other two factors, identifying potential farmers that are ready to accept and pay for RW seemed to be the main obstacle (Abu Madi *et al*., 2003). Abu Madi *et al*. (2003) performed their study on the farmers' willingness to pay (WTP) in Jordan and Tunisia.

Water pricing is recognized worldwide as a reliable tool for reducing the consumption of freshwater (FW). A series of increasing the tariff of freshwater in Israel between 1986 and the early 1990s, for example, led to an active drop in FW use in agriculture from 74% to 62% and, on the other hand, use of RW increased (Sanz, 1999; Ahmad, 2000; Abu Madi *et al*., 2003). Availability or accessibility to FW and concern for water quality and crop marketing were the major factors that made the farmers reluctant or hesitant to irrigate with RW. Farming profitability as well as the prices of FW and RW significantly influences farmers' WTP (Abu Madi *et al*., 2003).

In Crete, Farmers' WTP for recycled water to irrigate both olive trees and tomato crops was estimated at 55% of the freshwater price. WTP for olive oil produced from olive trees irrigated with treated effluent was estimated at 88% of its current market price. Environmental awareness and economic factors such as freshwater prices and incomes were found to be significant in explaining the willingness to pay for reused treated effluent and the produced crops, though clear differences exist between consumers and farmers (Menegaki, *et al*., 2007).

2.9 Methodology in Literature

In their study, Abu Madi *et al*. (2003) limited their sample size to 104 farmers due to: absence of the competent persons who could provide reliable information, farmers being suspicious or hesitant to cooperate, and logistical and budget limitations. In order to ensure the reliability of the collected data, Abu Madi *et al*. (2003) made sure to interview only knowledgeable respondents, relieve farmers' suspicions with small talks pre the interviews, and data crosschecking on 3 different levels – which resulted in rejecting 8 farmers for their misleading responses. Abu Madi *et al*. (2003) also used the Contingent Valuation (CV) method assuming the following hypotheses: WTP is expected to decrease if the RW's price increases, WTP is expected to increase if farmers' income increases or if the price of the competitive water sources increase, and finally, it will increase if the availability or accessibility of FW decreases.

Instead of open-ended questions, Abu Madi *et al*. (2003) relied on bidding and dichotomous choice (Yes/No) techniques as they offer higher values of willingness. Number of bids did not exceed 6 at max as recommenced in literature (Cooper, 1993; Alberdin, 1995; Hanemann and Kanninen, 1996), and ranged to cover: current price of RW, prices covering the operational costs of conveyance and distribution, operational & investment costs of conveyance and distribution, and operational costs of treatment (Abu Madi *et al*., 2003). In addition, Abu Madi *et al*. (2003) asked farmers if they would accept to pay any price for RW assuming that no more fresh water is available for irrigation.

2.10 Results of Surveys in Literature

In the study done by Abu Madi *et al*. (2003), 75% of interviewed farmers were interested in using recycled water (RW) for unrestricted irrigation. However, only 56.3% of the farmers agreed to use RW for restricted irrigation. All farmers out of 96 who were unsure or totally rejecting the idea of using RW for irrigation in their farms agreed that availability of and accessibility to fresh water was the major obstacle. Obstacles from major to minor were arranged as follows:

- Availability/ accessibility to freshwater (100% of farmers agreed).
- Distrusted water quality.
- Worries about crop marketing.

- Concerns for health impacts.
- Psychological aversion.
- Religious prohibition.
- Concerns for public criticism (less than 10% of farmers agreed).

The key outcome of the research was that farmers' willingness to pay was directly affected by the water price, and farmers were found to be unwilling to pay more than 0.05 $\$/m^3$ of reclaimed wastewater in Jordan and Tunisia mainly due to; quality concerns, comparatively easy access to freshwater, and price. Abu Madi *et al*. (2003) concluded that ambitious attempts to recover the full cost of treatment, conveyance and distribution in Jordan and Tunisia, considering the year the study was performed, might fail.

In a case study in the West Bank, Mizyed (2013) concluded that in spite of the absence of any serious objections to the reuse of treated wastewater, rural communities showed lower interest in reuse. However, that was explained by the shortage in suitable land for irrigated agriculture in the studied area, thus lower interest in reuse was already expected. Besides, poverty in the studied area was low and the availability of job opportunities in that particular area was higher than other parts of the West Bank. 1.4 ha was the average farm size in Mizyed's (2013) study with a family size of 8 people of which 3 people worked in agriculture. About 80% of those who were interviewed had high school education or more and 70% of them had at least 10 years of experience in agriculture. These results showed, according to Mizyed (2013), that agricultural communities were becoming more educated and self-conscious as well as capable of performing safety measures which are necessary for protecting public health. Therefore, relaxing the reuse standards seemed to be justified. Mizyed (2013) recommended that educating and training people might be necessary and should be intensive in the beginning, and should continue to introduce new crops and methods as it becomes less costly with time.

Mizyed (2013) also found that 83% of the interviewed farmers cultivated their own farms and that agriculture was taken as a part time job since it participated in less than 50% of the total income for about 75% of those who were interviewed. The fact that people relied more on rain-fed agriculture (which is less productive and depends on the variable rates of precipitation) than on irrigated forced farmers and members of their families to rely on diverse income beside agriculture. Mizyed (2013) found that 77% of farmers who were interviewed did not know about the Palestinian standards and regulations for treated wastewater reuse. However, 90% of them agreed that it is possible to safely reuse treated wastewater in agriculture and a similar percentage was willing to do so.

Irrigation water was not available for most farmers and would cost more than 2 USD/m^3 which is nearly four times the average price in major irrigated zones in the West Bank. The results found by Mizyed (2013) showed a discrepancy between the Ministry of Agriculture and farmers preferences. Farmers were more willing to reuse treated wastewater for irrigating fruit trees and olive tree (72%), and less of them (only 20%) preferred reusing treated wastewater for irrigation of fodder (Mizyed, 2013). However, the Ministry of Agriculture does not recommend the supplementary irrigation of olive trees (Mizyed, 2013; Nassar, 2019). Similar to the study of Abu Madi *et al*. (2003), farmers had their concerns about marketing and health risks (Mizyed, 2013).

2.11 Water Restrictions in Palestine

The Middle East and North Africa (MENA) region, with its population of about 336 million people or approximately 6% of the world's population, suffers from water scarcity, as the proportion of fresh water does not exceed 1% of the Earth's accessible resources (World Bank, 2011). Since the occupied Palestinian territories are part of the MENA region and are threatened as in the rest of these countries, the water sector in Palestine suffers from ***natural*** and ***political*** restrictions. TWW’s reuse in agriculture is encouraged in the Palestinian territories as a counter measure to these water restrictions in order to improve the agricultural sector, and save fresh water for other purposes.

2.11.1 Natural Water Restrictions in Palestine

There is an urgent need to develop water management strategies in Palestine to avoid a looming water crisis and the accompanying economic and social stagnation. Besides, the Palestinian situation is more complex than the rest of the countries in the region. The reason is that the Palestinian territories do not form a single geographical unit, and this means that the water resources in the occupied territories vary greatly and therefore must be solely studied and relatively independent strategies should be developed. In terms of the availability of fresh water and rainwater sources, the situation in the Gaza Strip is much worse than the case in the West Bank. Gaza is the most densely populated place on the planet and is the second most water-deprived area after Kuwait (Glover & Hunter, 2010).

In addition, the only source of fresh water in Gaza is the coastal aquifer that has suffered in recent decades from the depletion of its reserves (that is, the amount of water withdrawn is greater than the amount of water that enters the basin in the winter season) and its water has been seriously polluted as a result of the intrusion of salt water and other pollutants into it. This has led to catastrophic effects on the Palestinian aquifer, as the water suitable for human consumption in this basin does not exceed 5 to 10%, and if the current situation continues, the United Nations expects that within the next 15 years, the potable water in the Gaza Strip will be completely depleted. (PASSIA, 2011).

As for the conditions of the West Bank, it calls for cautious optimism. On the one hand, the West Bank enjoys traditional water resources and an annual rainfall rate that is better than the Gaza Strip. On the other hand, the West Bank is richer than many countries in the MENA region in terms of water resources. It is among the eight underground water basins. In Palestine, there are 3 partially or completely located in the West Bank (PASSIA, 2011), and thus the West Bank has the natural capacity to meet the water needs of its Palestinian population. However, the increase in water consumption rates and demographic shifts threaten to undermine this advantage in the coming decades.

In addition, when an independent Palestinian state is established, it is reasonable to assume that large numbers of Palestinian refugees in the diaspora will flow into Palestine, and this will necessarily increase pressure on the water supply. This brings us to the fact that while the challenges faced by natural water in the West Bank are not as dire as in Gaza Strip, this should not invite complacency or neglect. Policy makers should take advantage of the current situation in the West Bank to develop a clear long-term plan that takes into account these future pressures (Glover & Hunter, 2010).

2.11.2 Political Restrictions in Palestine

Since 1967, the governments of "Israel" have continued to impose severe restrictions on the water sector in the occupied Palestinian territories, violating the rules of international law. In August 1967, Military Order No. (92) granted full control of all water resources in the West Bank and Gaza Strip to military commanders. In the region, this military order was followed by more harsh measures. In November 1967, Military Order No. (158) was issued, according to which the Palestinians were prevented from establishing or repairing water infrastructure without the necessary licenses. As for Military Order No. (291) by December of the same year, it referred Ownership of Water Resources to Israel (PASSIA, 2011).

In September 1995, the Oslo II Interim Accord signed by the Palestinian and Israeli negotiators, which transferred to the Palestinian Water Authority the nominal control over water resources for Palestinian consumption. On scrutiny, it becomes clear that this transfer of power was a mere formality, a victory in name only, and the real control over the flow and volume of water destined for the West Bank remained with Mekorot (PASSIA, 2011).

There are two central mechanisms by which the government of Israel deprives the Palestinians of their share of the shared water resources: a legal mechanism and a physical one. According to the first mechanism, Israel classifies water as a resource for the Israeli public, forcing the Palestinians to apply for licenses from the Israeli government in order to dig new wells or repair old water or sewage networks, applications for related infrastructure licenses must pass through (18) a dramatic stage of government approval procedures. In addition to that, only a few of these applications have been approved by Israel, since 1967. Till 2003 for example, the Israeli government issued only 23 licenses (CESR, 2003).

This arbitrary policy has continued until the present time, and today there are more than 140 water projects awaiting Israeli approval. Many catastrophic effects resulted from these unjust and unjustified policies by the Israeli side, for example, the underdevelopment of the wastewater sector in the occupied territories. Until the last decade, there were only four cities in the West Bank in which wastewater treatment plants operated, and the rest of the population was forced to dispose of their sewage in the surrounding areas where they lived in unhealthy environments (World Bank, 2009).

Another legislative mechanism used by Israel is the systematic destruction by the occupation army of the water infrastructure and sewage networks in Palestine. In 2002 alone, the occupying army caused losses estimated at more than 7 million US dollars in the water supply and sewage infrastructure in the West Bank (Gerardi & Zimmerma, 2004).

Recently, Oxfam reported that since June 2009, Israel has carried out (300) demolitions against the water sector in the West Bank, including (80) reservoirs, (15) springs, (100) wells and one water pipeline. Israel sometimes claims the illegality of these projects to justify these demolitions, but it often does not give a definitive explanation (Oxfam, 2020).

In addition to legal obstacles, Israel has put in place a series of physical obstacles that enhance its control over water resources, thus preventing Palestinians from accessing them. In the West Bank, for example, Israel continues to build in settlements to prevent Palestinians from accessing major natural resources, including water. The strategic locations of settlements enclaves and the network of bypass roads aim to achieve maximum Israeli control over the main water resources, like the western groundwater aquifer and numerous wells and springs (Mclaughlin & Champion, 1987).

In the year 2002, the occupation authorities began building the separation wall, which is considered the biggest continuous physical obstacle that it imposes on the Palestinians, and it is clear to us that "Israel" wanted the path of this wall to be zigzag in order to include within it the majority of Israeli settlements and to eliminate the geographical contiguity of the West Bank and to annex and consolidate control over Palestinian lands and water resources (UNOCHA & UNRWA, 2008).

It is no coincidence, then, that upon the completion of the construction of the wall, it will have included the greater part of the western water basin, thus strengthening Israeli control over the most important shared water resources, and despite the fact that the International Court of Justice indicated that the separation wall constitutes a violation of international law, and that Parts of the Wall built in the Occupied Territories and East Jerusalem must be dismantled immediately, but this wall remains a grim reality before the eyes of Palestinians, and construction is still in full swing (ICJ, 2004).

According to estimates of the World Bank, the Jewish settlers in the West Bank control more than 140 wells in the West Bank that annually produce about 150 million cubic meters. The same underground sources in the West Bank which are used by Palestinians are also hugely exploited by settlers depriving the Palestinians from their rights of their own water. This led to a crisis which has exacerbated to the extent that Palestinian communities that used to enjoy abundant water resources are now forced to buy water from settlements and the Israeli water company “Mekorot”, which are the main cause of this crisis (World Bank, 2020) .

2.12 National Experience in Reuse Projects

The Palestinian experience in treated wastewater reuse is still young and poor. A study performed in 2005 has concluded that; excluding Al-Bireh WWTP, the major WWTPs of the Palestinian cities were overloaded (MEDAWARE, 2005; Adilah, 2010). However, several WWTPs have been constructed since then in the rural areas of the West Bank on a smaller scale. Many of these projects were funded by the NGOs to be accompanied by full sewer networks with house connections until the treatment plant while some other plants were established in areas lacking sewer networks. The remarkable variety of the international funders of these WWTPs and the applied wastewater treatment technologies in the villages has generated a creative environment of research and experience (EMWATER, 2004; Adilah, 2010).

Since 1990, more than 600 onsite grey water treatment units have been operating in the rural areas. Driven by the financial revenues, due to water consumption decrease, garden irrigation, and nutrients recirculation, the agricultural reuse is increasingly accepted, practiced and motivated by the government. However, there are still some difficulties regarding the implementation of these units including; financial considerations and lack of funds, health concerns, lack of experience and vision in the system’s performance and operational requirements (Mahmoud and Mimi, 2008; Adilah, 2010).

2.13 Wastewater Treatment Plants in Palestine

The sewage treatment plant in Al-Bireh was established in 2000 with German funding. It is designed with a capacity of 5,750 m^3/day and 11,500 m^3/day in wet weather (Al-Bireh Municipality, 2010). Services have been provided to approximately 95% of the population of Al-Bireh as well as two adjacent settlements. The maximum capacity of the sewage treatment plant was expected to serve up to 50,000 citizens. Domestic wastewater treatment is carried out using aeration tanks activated with sludge technology. The waste water first passes through the physical separation by two screens and then the biological process begins. In the aeration tank where sludge (biological masses) is formed, the flow continues to reach the filter tank and through settling the sludge blanket separation is directed and recycled to the activated sludge tank. The final treatment of sludge is the dewatering process in order to reduce the volume of sludge as well as to reduce pathogens (Al-Bireh Municipality, 2010).

El-Sayed and Tumaleh (2012) have investigated the efficacy of the wastewater treatment plant in Al-Bireh. In their study they stated that, in the sludge treatment process, the polymers are mixed with the sludge and then discharged by applying either centrifugal technology or belt pressing technology and both techniques work in parallel and this is due to the increased production capacity of sludge due to overloading. As a practical application, there is no chlorination step in sludge treatment in Al-Bireh WWTP, as confirmed by the plant operator. Then, the dried sludge is collected in small containers and collected at the site's wastewater treatment area to be transported by huge trucks to the Solid Waste Transfer Station in Ramallah to be dumped at Zahrat Al Finjan landfill near Jenin.

With regard to the sewage treatment plant in Jericho, the operation of the treatment plant started in June 2014 to receive sewage water from the sewer network of the Jericho Municipality and from cesspits in the surrounding areas at the implementation of the first phase. The purposes of the plant project according to the stakeholders are as follows; providing the area with an additional water source for hydro-irrigation as the area is located in a hot area and the available water resources are also limited. The benefit of using sludge as fertilizer has been taken into consideration since the beginning of the construction of the station. Another fundamental reason is to protect the groundwater and the Jordan River from pollution.

Jericho WWTP plant is located in agricultural land, south-east of the municipality, near palm plantations. Therefore, this can easily benefit the farmer by making use of the treated wastewater and the efficiently treated sludge. The design capacity is 9800 m^3/day. The project aims to serve the residents of Jericho by increasing the number of connections and the surrounding areas, including Ain Sultan camp, Al-Dyouk area, Al-Nuwaimah neighborhood, and Aqabat Jaber camp.

The technology adopted in the treatment of wastewater in Jericho was the activated sludge technology. The process consisted of the following; Two-channel sieving unit, two aeration tanks supported by blowers to further reduce nitrogen, two purification tanks for sludge settling including a sludge return pump to recycle the sludge to the aeration tank to maintain the vital source needed for aerobic digestion and finally a six-bed sludge dehydration bed unit.

On August 1, 2012, the wastewater treatment project began in Al-Tira Governorate. The hydraulic design capacity of the sewage treatment plant was 2000 m^3/day. The project was expected to serve a population of 25,000 residents of Tira and some household sewage connections. The technology applied was Membrane Bioreactor (MBR), which is a modified activated sludge system with ultrafiltration membranes. The MBR domestic sewage treatment facility was designed with reclaimed water quality of Class A requirements. According to the operator, the amount of pneumatically stabilized sludge (bio-waste) ranged from 3 to 4 tons per day. Aerobic stationary sludge is treated with polymers for dewatering by centrifugal machines. There are two centrifuges in the plant that run alternately but in emergency situations the two machines may work together. In fact, the dried sludge is stored from the water for a period of time until the right amount is ready to be transported to Zahrat Al-Finjan landfill, which is about 80 km away from the site.

In Nablus, the majority of homes are connected to the public sewage network, about 93%, and the rest are connected to cesspits. Wastewater treatment plant was established in West Nablus to cope with the increase in population and generated wastewater. The purposes are groundwater protection and preservation of local agriculture. Also, to prohibit farmers from using raw wastewater for irrigation (a previous farmers' practice) to protect public health. The wastewater treatment plant operation was started in July 2013 supported by a German technical assistance. The amount of treated water reached at that time 10,000 m^3/d, with a capacity of 14,000 m^3/d in 2020, with design effluent criteria higher than the limits accepted by the Palestinian Water Authority (PWA) and the Palestinian Ministry of Agriculture (MoA) (Nablus Municipality, 2017). The WWTP serves about 150,000 person living in the western part of Nablus City.

The processing technologies there start with coarse and fine sieves to capture the solid and semi-solid materials followed by the first settling tank, which reduces the suspended solids by percentage of 60%. The biological degradation and conversion of pollutants occur in the aeration tanks where the returned sludge is mixed with the fresh liquid and this stage of the activated sludge is controlled by maintaining the desired levels of certain parameters. The next unit is the final sedimentation tank in which the activated sludge is deposited and TWW is produced. A large part of the sludge is recycled to the feed aeration tank as mentioned earlier and the remaining part of the sludge is condensed in the sludge treatment units.

Finally, the five-step sludge line is run into the following units: Mechanical thickening sludge (basic thickening tank) in which the sludge is mixed with polymer before it enters into anaerobic digestion in anaerobic tank digester. This is important for thickening of solids in order to increase the efficiency of the alimentary digestion. The second unit is a secondary thickness unit and this step is done and monitored automatically according to a program executed by the station operators. Third, the anaerobic digester, in which the biogas (methane) and carbon dioxide energy-enhanced sediment is fermented in a ratio of 6: 3. The treated sewage sludge is transported to sludge dehydration ponds to reach 40%-50% solids. The last process is the sludge storage step, this needs time and effort as a wasteland, and this was done by the dredger and tractor factory. The stored treated sewage sludge is transported to the landfill of Zahret Al Finjan, which is about 40 km away. It is documented that the quantity transferred in September 2017 amounted to 320,230 tons (West Nablus Water Treatment Plant).

The first WWTP in the West Bank was established in 1972 in the city of **Jenin**, the city on which the case study is performed. Additional information about the WWTP of Jenin is presented in the ***study area section*** of ***chapter 3.***

2.14 Palestinian Treated Wastewater Status

Palestinian Agricultural sector facing a big challenge in agricultural water shortage resulted in reducing the irrigated agricultural land, which becomes around 19% compared with the rained agricultural land (MoA, 2017). Palestinian national climate change adaptation plan considered TWW as one of Agricultural water resource (EQA, 2016) and the Palestinian government push toward increase the amount of TWW to be reused in irrigation and other purposes since few years ago (PWA, 2014). The expected of TWW production from wastewater treatment plants that can be used in agriculture in West Bank by the year of 2022 shown in Table 1 (Nassar, 2019).

Table 1. Expected TWW production that can be used in the West Bank 2022 (Nassar, 2019)

WWT plant	TWW production yearly (MCM)
West Nablus	4.38
Jenin	1.64
Jericho	2.33
Anza	0.1825
Niet-Dajan	0.1825
Al-Taybah and Rammon	0.1059
Hajja	.1825
Sarra	.1825
Mesylia	.1825
Tayaseer	1.825
Hebron	5.11
Al-Teera	0.365
Rawabi	0.1825
Saeer	0.438
Total	20.1079

As shown in Table 1 the total TWW expected to be reused in irrigation annually by the year of 2022, around 20.1 MCM which can represent around 13 % of the current conventional agricultural water (MoA, 2017) and can be consider as additional agricultural water.

The second strategic objective for the National Agriculture Sector Strategy (2017-2022) is: "Natural and agricultural resources sustainably managed and better adapted to climate change".

Therefore, MoA aimed to increase the availability of conventional and unconventional water resources for both crop producers and livestock breeders (MoA, 2017).

There is a possible to increase the amount of TWW by establish new WWT plants where 56 % of the residents are connection with sewerage network system while the existing WWT plants cover around 50 % of the total wastewater production in Palestine (PWA and MoA, 2014).

2.15 Palestinian Treated Wastewater and Reuse Regulations

Ministry of Agriculture (MoA), Palestinian Water Authority (PWA), Palestinian Standards Institute (PSI), Palestinian Environmental Quality Authority (EQA) and others showed great interest for treated wastewater and the importance of treated wastewater reuse considering the Palestinian situation. Since 2003, the Palestinian government has issued the Agricultural Law (No 2/2003) that defined the TWW as a water source. As well, Palestinian Standards Institute has issued at that time a Treated Wastewater Standard (PSI 742-2003), which identified the important parameters levels to be taken into consideration in case wastewater is decided to be treated. The required standards were identified so that the produced TWW could be discharged or reused. Since 2011, MoA issued instructions for treated wastewater reuse in agriculture (MoA Technical Instructions/2011) based on the Agricultural Law (No 2/2003).

Furthermore, Palestinian Standards Institute has issued the Obligatory Technical Regulations (PSI TR 34, 2012) Annex 3 that divided the quality of treated wastewater specialized for irrigation into 4 categories, high quality (A), good quality (B), moderate quality (C), and low quality (D) and it also contain the obligatory regulations and technical instructions requirement for controlling, permitting, conveying and reusing of TWW in irrigation.

Recently, Palestinian Standards Institute has issued the Treated wastewater – Treated Wastewater Effluent for Agricultural Purposes (Restricted) (PSI 742-2015) in 2015 to cope with the gradual increase in the production of TWW. It is determining the classification of treated wastewater quality and the crops which are allowed to be irrigated with TWW on different quality levels, including fodder crops, fruits, ornamentals and others. It also states the number of barriers that are considered in the approach of utilizing each treated wastewater quality in irrigation for different crops. The addressed barriers include actions and behaviors such as positioning the emitters far away from crop canopy, utilizing subsurface drip irrigation system, utilizing filters for irrigation water, storing irrigation water, cutting off irrigation before harvesting and some other possible actions that the farmer could be utilizing in their farms to reduce the possibility of crop's and fruit's contamination.

2.16 Irrigation System Selection and Water Use Efficiency (WUE)

Researches have been made on the relationship between the selected irrigation system and crop productivity. Besides, recognizing the scarcity of water, the food shortage, and seeking the highest profit for the exported agricultural products have led to intensive studies on the Water Use Efficiency (WUE). Some of the world wild recognized irrigation systems are: surface drip irrigation (SDI), sub-surface drip irrigation (SSDI), shallow sub-surface drip irrigation (S3DI), sprinkler irrigation system and furrow irrigation system (Sorensen *et al*., 2021). The most common irrigation systems in Palestine are SDI and sprinkler irrigation (Nassar, 2019). Realizing the necessity of exploiting all the available resources while achieving the highest WUE, the Palestinian Ministry of Agriculture has recommended the Palestinian farmers to benefit from the treated effluents in the irrigation of alfalfa crops using SSDI; considering it as the most suitable irrigation system that would reduce the water losses resulted from evaporation. In the same contest, less evaporation means less salt accumulation on the surface of the soil which is a huge threat to the germination of seeds (Nassar, 2019). According to Nassar (2019), the recommendation of the MoA was more related to visioning the SSDI system as a barrier for health protection, especially when compared to sprinkler irrigation, rather than being based upon previous knowledge about a tested relationship between the selection of irrigation system and WUE.

Şahin *et al*. (2005) stated that drip irrigation has become a widespread irrigation system considering the concerns related to water scarcity around the world (Imam *et al.*, 2021). Drip irrigation means the application of a steady flow of water at constant rate and low pressure to the root zone directly, using drippers on or below the soil surface (Imam *et al.*, 2021). The short distance to ground as well as the low pressure condition minimize the water splash and reduce the water losses (Ali, 2011; Imam *et al.*, 2021). Hussein (2015) considered SSDI as one of the most effective irrigation techniques which is known for its high WUE due to; the small amounts of water provided at short intervals and the reduction of water losses, the elimination of water evaporation, and deep percolation, which eventually improve the plant's uptake of water and nutrients (Imam *et al.,* 2021). Despite the requirement of a skilled management in order to improve the systems' performance, Waller and Yitayew (2016) summarized the benefits of SSDI in the following points:

- Saving water.
- Improving crop yield in terms of quantity and quality.
- Facilitating the application of fertilizers.

In their study, Imam *et al.* (2021) compared between several irrigation systems including SDI and SSDI, and found that SSDI with double inlet was the most efficient in all the measured parameters by achieving; lowest pressure drop, highest emission uniformity, highest crop yield, and highest water use efficiency.

It is worth mentioning that S3DI system had a greater yield than SSDI in a study by Sorensen *et al.* (2021) for both row patterns and seeding rates.

In a comparison between using SDI and SSDI for growing one dunum of Pearl millet with TWW during the ANERA project in Jenin City in a five years period (the life span of the irrigation network), and in terms of total cost, revenue and profit of selling the produced forage, Nassar (2019) found that SSDI is favoured in all three aspects where the profit is almost doubled, See Table 2. The total cost at the end of the five years were close for both systems, however, the clear difference in productivity in the case of SSDI compared to SDI resulted in a higher revenue rate and higher profit. In his financial analysis, Nassar (2019) fixed the following assumptions for both systems:

- Prices were fixed over five years,
- TWW's price was fixed at 0.19 US$/$m^3$ (0.7 ILS/m^3)
- Annual water requirement: 365 m^3 /dunum/year
- Pearl millet forage price: 0.27 US$/kg

Table 2. Financial analysis to compare between SDI and SSDI (Nassar, 2019)

Item	SDI	SSDI
Total **cost** in five years (US$)	2,160	2,090
Total **revenue** in five years (US$)	5,815	8,850
Total **Profit** in five years (US$)	3,665	6,760

Chapter Three

Study Area & Methodology

As stated earlier, the main goal of the research was to explore for the driving forces that led the Palestinian farmers in the West Bank, taking Jenin as a case study, to start relying on the municipal treated wastewater for irrigation purposes and the common practices in this sector. This chapter introduces the methodology used in this research, which can be classified as a survey-based research, as well as a description of the study area.

3.1 Study Area

The case study was performed in the city of **Jenin**, in the plains of Marj Ibn Amer, and the treated wastewater source was the effluent of the wastewater treatment plant of Jenin's city, see Figure 1. In this section, an identification of the studied area and a general description of the city of Jenin and its WWTP are presented in the following sub-sections.

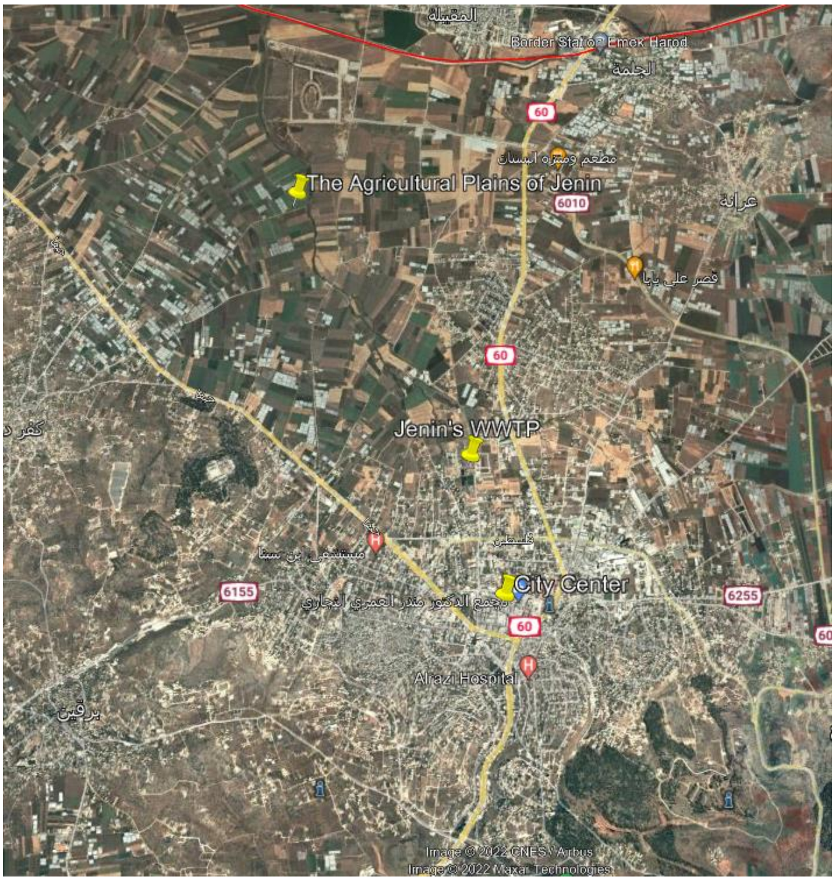

Figure 1. Location of the WWTP and the targeted agricultural plains to the north-west of the city center (Google Earth Pro, 2022)

3.1.1 Geographical Location and Population

The city of Jenin is located at the confluence of latitude 32.28 north and longitude 35.18 east. Jenin governorate is considered a confluence line for the three environments, the mountainous, the plain and the Ghouri, and thus it became an important transportation point, linking the roads heading between Haifa and Nazareth in the north and to Jerusalem and Nablus in the south (Palestinian Central Bureau of Statistics, 2010).

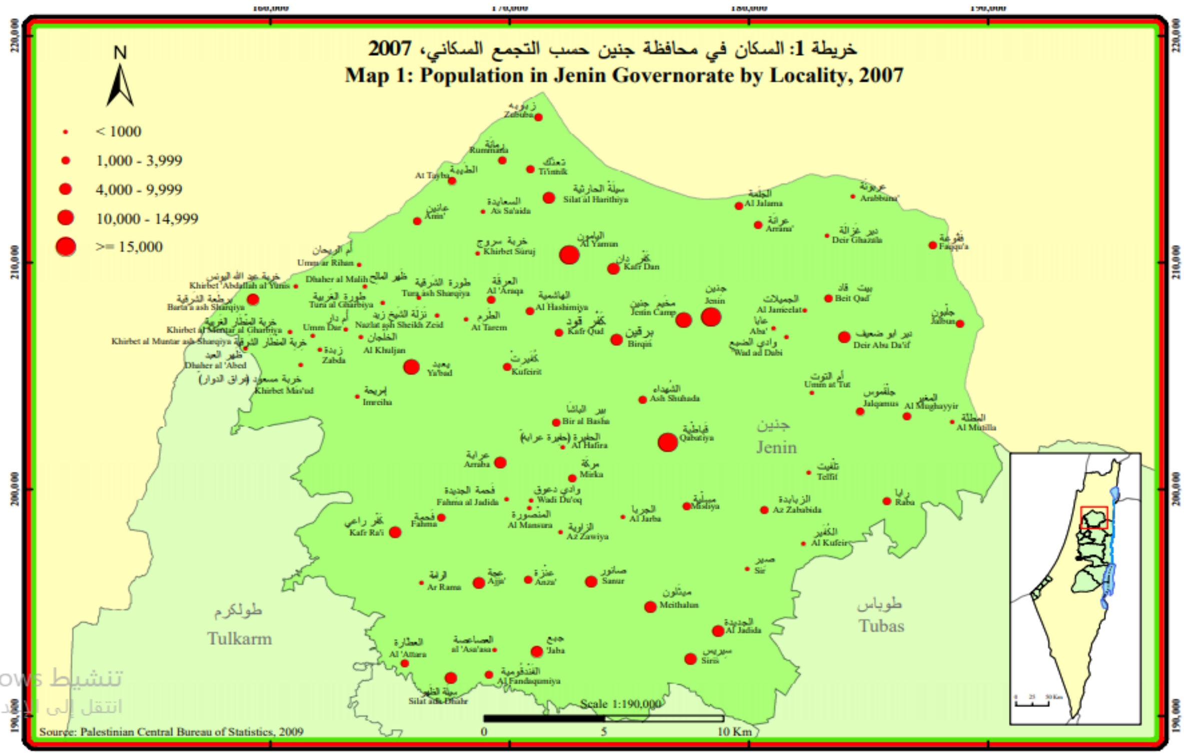

Figure 2. Population in Jenin Governorate by locality 2007 (PCBS, 2010)

Figure 2 shows the population distribution in Jenin Governorate by locality in 2007. The highest populated localities are gathered around the city center of Jenin. Currently, the WWTP in Jenin is receiving the sewage from Jenin city and its camp, and it is expected to receive additional load from some of the nearest localities in the near future. Birqin local council has already started their wastewater conveyer project to transfer their sewage to Jenin's WWTP after getting the approval from Jenin Municipality (A. Humran, personal communication, April 20, 2022). In mid-2022, the population of Jenin Governorate reached (345,875) people, of which (54,823) inhabitants are the residents of the city of Jenin, (11,443) inhabitants are housed in Jenin's camp, and (279.609) inhabitants are distributed among 73 villages and localities belonging to Jenin Governorate (Palestinian Central Bureau of Statistics, 2017).

3.1.2 Economic Activity

The residents of Jenin's governorate practice many economic activities. When compared to construction, commerce, restaurants and services, agriculture comes later in the list of the practiced economic activities with a percentage of 10.4% amongst both genders (Palestinian Central Bureau of Statistics, 2019). However, it is well known that agriculture was the major craft practiced by the Palestinian society, as elsewhere in the Arab region, in the early decades of the twentieth century (Stein, 1987). Agriculture was the major local resource in the region, and this craft decreased for several reasons. For example, in Jenin, the most important reason of this obvious decrease was the Israeli occupation of many lands of Jenin governorate in 1967, and the migration of many residents to Jordan due to the 1967 events. Relying on rain-fed agriculture has led to the agricultural sector being heavily affected by the climate change and shortage of water quantities, considering the obstacles imposed by the Israeli policy on the Palestinians digging new wells (Palestinian Central Bureau of Statistics, 2010).

The residents grow a variety of agricultural crops from fruit trees to field crops and vegetables. Some of the agricultural industries in JC are olive presses and grain mills (Palestinian Central Bureau of Statistics, 2010).

3.1.3 The Climate

Jenin's climate is generally moderate, because it belongs to the Mediterranean climate with its well-known characteristics. Besides, winds of different directions blow over the city, but the prevailing winds are western, southern and eastern winds. In the period between 2010 and 2018, excluding 2011, the annual mean of air temperature was stable between 21.0 °C and 21.8 °C, see Table 3. The highest annual mean of maximum air temperature in Jenin City was recorded in 2010 at 28.0 °C, and the lowest annual mean minimum was recorded in 2011 at 15.8 °C (Palestinian Central Bureau of Statistics, 2018). In 2020, air temperature in Jenin was higher than its mean average by 1.6 °C (PCBS & PMD, 2022).

Except for Jericho, Jenin comes at the end of the "Amount of Rainfall" list when compared to the other Governorates of the WB of Palestine (Nablus, Ramallah, Hebron, Bethlehem, Tulkarm, and Jerusalem). The accumulated precipitation in Jenin from the beginning of the winter season 2021/2022 until March 14, 2022 reached 432.7 mm (PCBS & PMD, 2022), and the total precipitation in year 2020 was 575 mm, while the annual average precipitation in Jenin was 486 mm as stated by PCBS & PMD (2020).

Table 3. Temperature (°C) and Precipitation in Jenin Governorate (mm) during the period 2010-2018 (PCBS, 2018).

Type of Reading	Year								
	2010	2011	2012	2013	2014	2015	2016	2017	2018
Temp (avg)	21.8	20.2	21.0	21.0	21.1	21.0	21.5	21.2	21.8
Temp (max)	28.0	25.5	27.8	26.4	26.6	26.5	27.0	26.8	26.9
Temp (min)	17.4	15.8	15.9	16.4	16.5	16.6	16.9	16.6	17.7
Precipitation	336.5	459.3	544.9	480.0	297.4	529.1	438.8	175.4	763.0

Table 3 shows the high fluctuation in the annual cumulative precipitation that falls on Jenin. Notice the huge variation between the years 2017 with a precipitation of 175.4 mm and 2018 with a precipitation of 763.0 mm.

3.1.4 Water Sources in the West Bank

There is a variety of potable water sources in Palestine, and these sources are:

First: Rain

Rain is one of the main sources of water in the West Bank. Rainfall is characterized by fluctuations from year to year, and the amounts of rain change from one region to another according to the topographical and spatial changes. The amount of rain in the higher areas exceeds 600 mm per year, and falls below this level whenever the area's height is lower than sea level, and reaches 100 mm in the Jordan Valley and Dead Sea areas. However, the average rainfall in WB reaches 540 mm annually which is equal to 2970 MCM/y, distributed as follows (Nazer et al., 2010; Aboushi, 2017):

- 77 MCM/y as runoff
- 7 MCM/y is the share of rainfall being harvested
- 2207 MCM/y wasted in the evapotranspiration
- and 679 MCM/y infiltrated into the ground water

Second: Surface Water

The water of valleys in which rainwater flows represents the surface water in the winter, and the valley water is an important source if it is exploited in a sound technical manner. The total amount of water flowing through the valleys is estimated at 110 million cubic meters annually. The Jordan River is also considered among the surface water sources, as its water flows from the far north and at an altitude of 2200 meters above sea level to the Dead Sea and at an altitude of 350 meters below sea level. Its historical annual discharge rate is 1400 million cubic meters, and Palestine's share is 257 million cubic meters annually, but no amount of it is obtained due to the Israeli occupation's control of the river. The Jordan River is the only permanent source of surface water in the West Bank and Palestine as a whole (PWA, 2017).

Third: Ground Water

Groundwater is the main source of water in Palestine representing 95% of total water consumption according to Nazer (2017), where groundwater is extracted from three main basins in the West Bank, namely the western, eastern and northeastern aquifers, see Figure 3, and the costal aquifer in Gaza Strip (Nazer, 2017; Aboushi, 2017). Both western and northeastern aquifers are topographically shared between Palestinians and Israelis. Eastern aquifer is located completely within the borders of the WB. However, an influential part of its water is classified as saline water, and still, the Israeli settlements have their own share of its water (PWA, 2017).

The renewable storage capacity of these basins is around 675-794 million cubic meters, and the western basin is the most productive in terms of the amount of renewable water, reaching about 318-420 million cubic meters annually, followed by the eastern reservoir, which amounts to 125-195 cubic meters per year, and 50% of its water is saline. As for the northeastern, the amount of renewable water is about 145-170 million cubic meters annually (PWA, 2017).

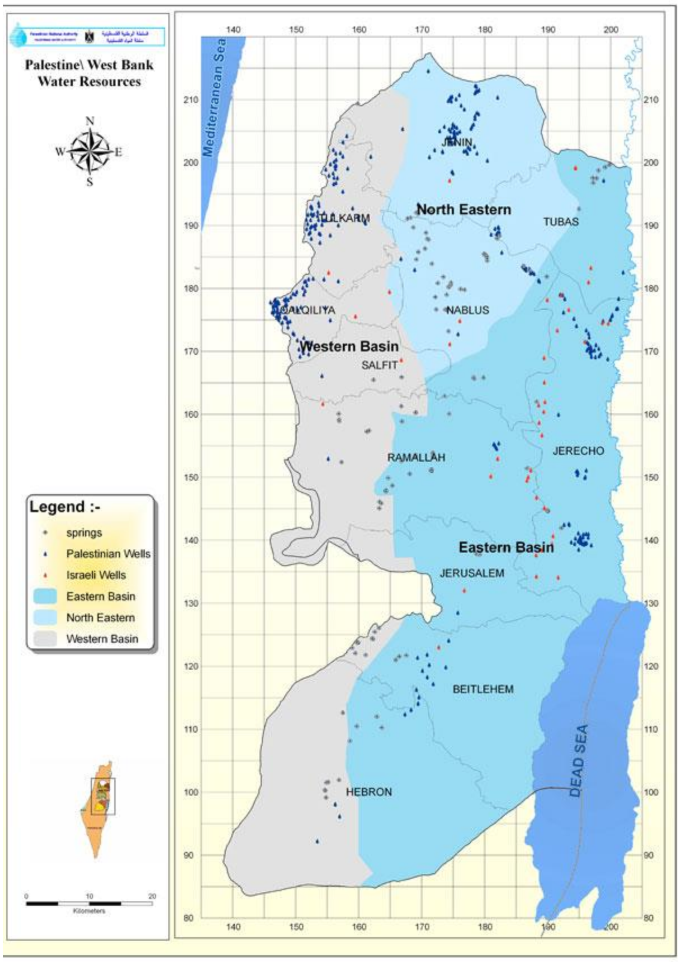

Figure 3. The three aquifers in the WB (PWA, 2017)

Water levels are affected in the three aquifers by the annual rainfall rate, as these aquifers are recognized as renewable aquifers that depend mainly on rainfall rates. Figure 4 shows the water quantities abstraction approved by *Article 40* in the *Oslo II Interim Agreement* for both sides (the Palestinians and the Israelis) to be exploited from the WB aquifers, and Table 4 shows the Palestinian and the Israeli utilization of these aquifers in 2015.

Table 4. The Palestinian and Israeli utilization (MCM) of the West Bank's Aquifers in 2015 (PWA, 2017).

The Utilizing Party	Western Aquifer	North-Eastern Aquifer	Eastern Aquifer	Total
Israeli Occupation	≥411	≥103	≥150	664
Palestine	37.6	21.6	64.8	124

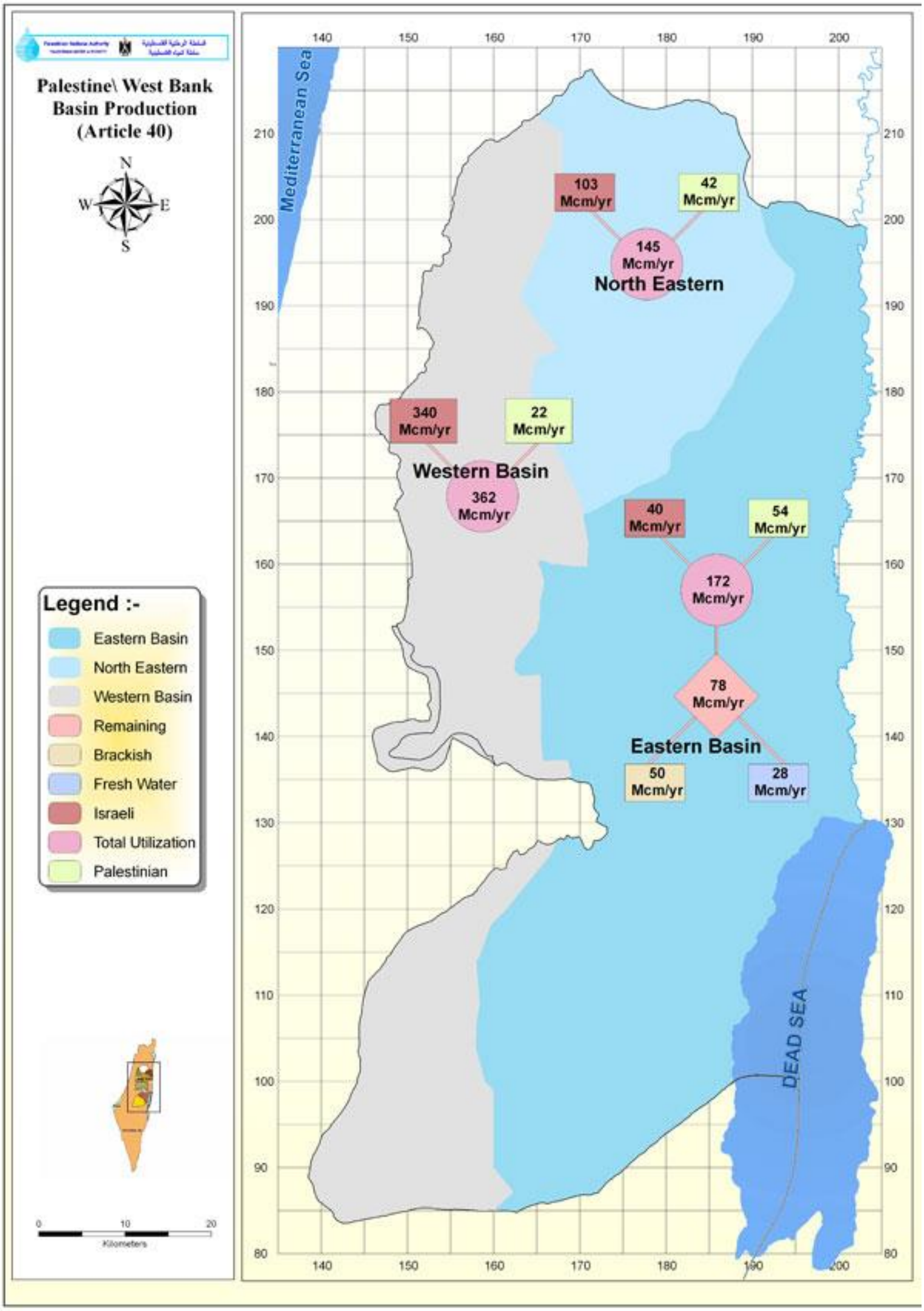

Figure 4. The WB's aquifers production and the agreed on abstracted quantities (PWA, 2017)

According to the PCBS (2021), in 2019 the recorded number of agricultural wells in the WB was 333 pumping 53.9 MCM/y for agricultural consumption and the total number of wells was 399 pumping 101.8 MCM/y for different water usage in the WB. It is worth mentioning that in addition to the agricultural usage of the pumped water, agricultural wells in the WB also pumps a share of the extracted water for the neighboring households for daily man-use.

3.1.5 Water sources in Jenin Governorate

The rain season in JC starts in mid-October during which almost 3.2% of the annual rainfall falls, and extends to April. Around 80% of rainfall falls within three months in winter from November to February (ARIJ, 1996; Aboushi, 2017).

In addition to the water purchased from the Israeli party and Mekorot based on the Oslo agreement, groundwater is the main source of water in Jenin governorate, represented by wells and springs. In 1996, the number of artesian wells in Jenin governorate reached 63, of which 58 wells were owned by the private sector used mainly for irrigation purposes. The remaining five wells belonged to the municipalities in the governorate and were exploited for domestic use (ARIJ, 1996; Aboushi, 2017). Since most of the major wells were under the Israeli control, the residents of Jenin city had to dig a number of shallow wells to meet their needs of water risking it without getting a license, and the amount of water extracted from those wells was very limited. Shallow wells could have not been counted due to the absence of the license (Saqer, 2005; Aboushi, 2017).

In 2019, the recorded number of agricultural wells in Jenin governorate was 22 pumping 1.8 MCM/y for agricultural consumption and the total number of wells was 33 pumping 8.2 MCM/y as a whole consumed in different areas of usage including agricultural, industrial, institutional, and domestic (Palestinian Central Bureau of Statistics, 2021).

3.1.6 Soil in Jenin City

The agro-biodiversity of several components is highly distinguished in the historical Palestine, and soil is no exception. Therefore, from north to south and east to west in Palestine, a variety of soil types are found. Climate is a major factor for soil formation. Beside wind, there are two climatic factors that have the most influence on soil formation, namely temperature and precipitation, as they work on the weathering of rocks and minerals. The distinguished variety of climate types in Palestine is the reason behind the agro-biodiversity, and thus the soil diversity. It is recognized that the rate of soil weathering is highest in the eastern parts of the

West Bank, followed by the eastern-southern parts, and is lowest in the central parts of the Bank. The soils in some areas of the WB are richer of nutrients and more suitable for agriculture than others. The plains of Jenin are characterized to be amongst the most fertile in the WB. The soil in the Jenin area is rich in organic matter and nutrients and suitable for agriculture (Hamarsheh, 2010). Soils in Jenin City are divided into several main types, the most important of which are:

First: Red Soil (Terra Rossa)

This type of soil covers the equivalent of 50% of the land area in the Jenin area. This soil developed from limestone rocks that are widely spread in the Jenin Governorate, and this soil varies in its characteristics and depth throughout the Jenin Governorate. Ojjeh, Mithlon, Sanur, and Marj Ibn Amer (Hamarsheh, 2010).

Second: Randsina Soil

There are two types of brown Randzina and pale Randzina. The brown Randzina soil is concentrated in the eastern areas of Jenin Governorate. It is red-brown in color. It is considered soft chalk and marl rocks. It is a soil rich in organic matter and is used in the cultivation of agricultural crops such as wheat and fruit trees such as olives. As for the pale Randzina soil, it represents a small area in the governorate and spreads south of the town of Yabad It contains a high percentage of gray lime and gray alluvial soil, and its main material is fine chalk (Hamarsheh, 2010).

Third: Grammo Soil

This soil is characterized by being distributed in flat terrain conditions. Its origin is due to alluvial soil and is used for the cultivation of field crops, and it has the advantage of retaining moisture in summer crops (Hamarsheh, 2010).

In addition to the availability of water sources, there are many monitoring tools which are of no less importance just like the supervision on soil degradation due to erosion, acidification, salinization and many other factors. The soil degradation in Palestine is recognized due to two main categories of soil deterioration processes (soil displacement due to erosion by water or wind, and in-situ soil deterioration for either chemical or physical reasons). The in-situ reasons of soil degradation in the WB include: water scarcity, absence of good control on dumping sites, and the frequent, unplanned use of fertilizers (ARIJ, 2007; Hamarsheh, 2010).

3.1.7 Agricultural activity in Jenin governorate

The city of Jenin drives its name from its green fields, orchards and gardens. After the shifting of an influential portion of the citizens of JC from agriculture towards other economic activities, and even after the recent demolish and transfer of many orchards of the city into housing and built up areas; Jenin District still maintains the largest vegetation area in the West Bank. The latest collected statistics by the PCBS concerning the cultivated areas in Palestine belong to the years 2010 and 2011. The total cultivated area of the city in that period reached 199,752 dunums, while the largest share went to the horticulture trees with an area of 118,285 dunums. The cultivated area of field crops reached 58,997 dunums and 22,470 dunums of the city's land was planted with vegetables. In contrast to the percentage of rain-fed vegetables of only 15.3%, the percentage distribution of rain-fed field crops in Jenin, in comparison to irrigated, reached 98.8% in 2011. Similar to field crops, 93.2% of the horticulture trees northern the WB is rain-fed. In terms of area, the rain-fed area of field crops was 58,264 dunums and the irrigated area was 733 dunums producing 17,199 metric tons in aggregate. Productivity of irrigated crop fields reached 1.838 ton/dunum compared to 0.272 ton/dunum (around 0.15%) in the case of rain-fed crop fields (Palestinian Central Bureau of Statistics, 2011).

Knowing that the choice of reusing TWW is more directed towards the irrigation of crop fields and horticulture trees than vegetables in the Palestinian agricultural policy, and considering the previous statistics, the importance of reusing TWW in JC for agricultural purposes is increased. In 2014, the American Near East Refugee Aid (ANERA) funded an irrigation project in JC using TWW that aimed to irrigate 3000 dunums of crop fields and horticulture tress in its scope, in line with the vision of the MoA which schemed to specify the region shown in Figure 5 to be irrigated with TWW. The project started with 500 dunums; 400 dunums of alfalfa and 100 dunums of trees (M. Alsheta, Personal communication, April 15, 2020). In 2020 at the time the data was collected for the thesis, and after six years of the irrigation project's debut, the cultivated area using TWW reached 585.5 dunums before starting deteriorating to its lowest levels in 2022.

Figure 5. The targeted agricultural area in Marj Ibn Amer to be irrigated with TWW, as planned by the MoA (MoA, 2015; Nassar, 2019)

3.1.8 Wastewater treatment plant in Jenin Governorate

The sewage treatment plant in Jenin, to the north-west of the city, is the first treatment plant in the West Bank, which was established in 1972 on 2.7 hectares. It is worth noting that it was primitive in its technology and the effluent's characteristics. The treatment was not in conformity with the Palestinian specifications and the World Health Organization (WHO) until its rehabilitation in 2009. In 2009, the treatment plant was rehabilitated in order to raise the specifications of treated water through the contribution of the German Bank for 1,800,000 euros and a contribution from the municipality for 1,500,000 US dollars. The project was supervised by the UNDP in coordination with a group of civil engineers led by Eng. Alsheta from the side of Jenin's Municipality who continued to operate and maintain the treatment process in the WWTP until 2019 (M. Alsheta, Personal communication, April 15, 2020).

The monthly operation cost of the WWTP is 57,000 Dollars on its full capacity, including electricity and salaries of staff operating the plant. The treatment plant has a daily design capacity of 10,000 m^3. In 2020, the daily average flow was estimated at 7,5000 m^3 in dry weather. However, the most recent readings taken in Aug, 2022 indicated a daily average of 5000 m^3. In winter the flow is discharged in the valley instead of being received into the plant for technical issues. The treatment plant serves 45 % of the population of the city of Jenin, about 20,000 inhabitants, and the Jenin camp, which has a population of 15,000, a total of 35,000 inhabitants. The rest of the population in JC either dumps their sewage into household cesspits or into Al-Maqta Wadi wherever a sewer network exists. The permeable karstic geology in Palestine allows the flow of the sewage dumped into cesspits through the earth layers contaminating the shallow ground water bodies. Whenever these cesspits become impermeable, the sewage is discharged out of them on a regular base and transferred to the WWTP. Mainly in winter, the largest portion of the wastewater and rainfall which enters the Wadi, crosses the Palestinian-Israeli borders, and is then taxed by the Israeli Occupying Sate for polluting the environment to allocate the cost of treatment. However, the treated effluent by the border WWTPs is totally exploited by the Israelis and no water at all is given back to the Palestinians – the actual funders of the treatment process considering the paid taxes (N. Abu Ghazaleh, Personal communication, March 13, 2022).

The WWTP consists of two treatment stages: physical and the biological. The physical stage begins with a stone trap channel for large stones and relatively large dirt that is cleaned periodically, followed by two mechanical screens and a manual screen that is cleaned on a daily basis. The water then passes through two grit removal chambers into a Parshall flume measuring the wastewater's speed and quantity before entering the biological treatment ponds (N. Abu Ghazaleh, Personal communication, March 13, 2022).

The biological stage is divided into two separate lines with a total of six lagoons followed by a collection pond. Each line starts with two aerobic treatment lagoons, in which wastewater is fed with Oxygen for the aerobic treatment processing using four surface aerators in each lagoon. The third lagoon in each line is a clarification tank designed to physically precipitate the sludge before the TWW exits to the final collection pond added by ANERA for the Irrigation project to pump TWW to farmers as needed. The TWW is collected in the last pond to be examined and pumped to the targeted agricultural lands through eight gravel filters, which are constantly cleaned, followed by a chlorination step (N. Abu Ghazaleh, Personal communication, March 13, 2022). Figure 6 is an aerial photo of Jenin's WWTP, obtained from Google Earth on Aug 13, 2022, showing four aerated lagoons, two clarification tanks, and the collecting pond constructed by ANERA.

Figure 6. An aerial photo of Jenin's WWTP **(**Google Earth Pro, 2022**)**

3.2 Field Visits, Personal Interviews, and Data Collecting

In a case study based research, field visits represent an important source of information and the corner stone that allows for a proper evaluation of the situation in the targeted area. A good understanding of all the variables in the study area concerning the subject of the study before constructing the questionnaire and even before tuning the set of research questions in its final form, was obtained through the direct contact with the leading people who were directly involved in ANERA's agricultural reuse project. Collecting the relevant information from different parties left a huge impact on understanding and imagining the full picture of the reuse project, the sequence of events, and the mentality of the farmers. The parties with relevance to the reuse project were; Jenin Agriculture Directorate - the Palestinian Ministry of Agriculture (MoA), Jenin's WWTP - Jenin Municipality, Marj Ibn Amer farmers' association, and ANERA connecting all these parties and involving them each in its speciality. Here is a list of the interviewed experts:

- Engineer M. Alsheta: the former executive engineer of Jenin's WWTP.
- Engineer N. Abu Ghazaleh: the current executive engineer in Jenin's WWTP.

- Engineer M. Naeem: a former agronomist at ANERA and the most involved expert in Jenin’s reuse project.
- N. Atari: Head of Irrigation Section - G.D. of Soil/Irrigation and Natural Resources, Jenin Agriculture Directorate, Jenin, Palestine.
- A. Nassar: Head of TWW Uses Division at Ministry of Agriculture, Ramallah, Palestine. And a master student at Birzeit University who performed a thesis on the same reuse project by ANERA holding the title; “Effect of Irrigation with Treated Wastewater Using Surface and Subsurface Drip Irrigation Systems and Different Irrigation Quantities on Pearl millet Productivity and Water Use Efficiency”.

Each one of the mentioned experts has played a specific and crucial role in this research. Information regarding the WWTP of Jenin was provided by Alsheta and Abu Ghazaleh as indicated in ***section 3.1.8***. N. Atari (Personal communication, August 12, 2022), head of irrigation section in Jenin Agriculture Directorate, has provided us with the results of some tests that were performed on the treated effluent by different parties. On the other hand, the interview with Nassar was more conceptual as he provided the needed guidance and support throughout the study, not to mention the high value of his master thesis in the subject of study as well as the data provided by him on request for the research, such as the English version of the “Technical Regulations for the reuse of treated wastewater in agricultural irrigation (PSI, TR-34, 2012) – Annex 3” (Nassar, 2019). Last but not least, M. Naeem (Personal communication, January 20, 2020) helped constructing the questionnaire due to his wide knowledge of the smallest details of the reuse project and the daily events and practices of the farmers. Figures 7 & 8 are a couple of photos taken in the field visit to Jenin’s WWTP in July, 2020. The photos in Figures 9 & 10 were taken during a visit to an alfalfa farm irrigated with TWW in Jenin, in April, 2020. Figure 11 shows a photo taken in 2016 for an alfalfa farm irrigated with TWW that was provided by M. Naeem (Personal communication, January 20, 2020).

Figure 7. The aerobic biological treatment section in Jenin's WWTP (Field visit, 2020)

Figure 8. Gravel filters in Jenin's WWTP (Field visit, 2020)

Figure 9. Alfalfa crop irrigated with TWW in Jenin (Field visit, 2020)

Figure 10. Alfalfa crop irrigated with TWW in Jenin (Field visit, 2020)

Figure 11. Alfalfa crop irrigated with TWW in Jenin in 2016 (M. Naeem, Personal communication, January 20, 2020)

3.3 Research Questions

The first crucial step in any research is to specify the research questions or goals. This step is necessary to determine the type of data, which is required, and the best fitting way for collecting and analyzing it. There were major and minor questions to be addressed in this research. The two major addressed questions in the thesis spotted the light on the driving forces behind the Palestinian famers' acceptance of municipal treated wastewater in irrigation as well as the common practices performed by the farmers involved in the treated wastewater reuse. Other questions that matter were to determine: the level of knowledge the farmers had, supervision impact on farmers' actions, the effects of using treated wastewater on many aspects, sustainability in light of the impact on profit and economy, future vision by farmers and Ministry of Agriculture, and finally the recommendations and the next step towards development.

3.4 Preparing the Questionnaire

Data from the farmers were obtained through personal meetings and filling a questionnaire. The Questionnaire consisted of a mixture of structured and open-ended questions, as well as supplemental questions that answer the research questions and were categorized into the following sections:

1. Identifying information of the farmers, including; age, gender, date of interview and contact information.

2. General information regarding the farms irrigated with TWW, including; area, number of labours, type and quantities of water used in irrigation, location with regard to the nearest housing area, and whether the farms were fenced or not.
3. Water prices, including; fresh water and TWW prices, and the most preferred TWW's price by the farmers who were not satisfied with the current price.
4. Measuring the farmers' level of knowledge, and included; the highest educational degree obtained by the farmers, the farmers' knowledge in environmental benefits and nutritious content of the treated effluent as well as the environmental and health risks when dealing with TWW, knowledge in the safety measures and the Palestinian TORs associated with the agricultural reuse of TWW, and whether they have received any training or their willing to increase their knowledge in the field of reuse.
5. Farmers' practices, which included; identifying the planted crops, fertilizers' usage, irrigation system, safety measures considered when dealing with TWW and whether a direct contact with the water occurs, the period separating between last irrigation and harvesting, the considered safety measures while harvesting, the months during which the TWW is used in the farm, and whether the product is labelled as "irrigated with treated wastewater" before it's sold to the customers.
6. Supervision, which included; which farms were visited by official supervisors identifying the official party, the imposed sanctions on farmers for violating the Palestinians regulations, and the frequency of testing water, plant, and soil samples.
7. Motives, obstacles, worries and concerns, divided into two major questions; the motives and obstacles for reuse in the beginning of the reuse project funded by ANERA, and the remaining worries and concerns at the time the farmers were interviewed.
8. The effects of reuse on; quantity and quality of crops, unpleasant odours spread, insects increase, soil quality, human health, marketing, and irrigation system's functionality.
9. At the end of the questionnaire, the farmers were given a space for adding their own commentary describing their own experience in the reuse business.

The questions included in the questionnaire were directed to the farmers in Arabic, the local language of the Palestinian community, and the interviewer was knowledgeable in the characteristics of treated wastewater and the relevant information related to the subject of the research (environmental and economic values of using treated wastewater for irrigation, health impacts, safety measures that are considered when irrigating with treated wastewater, laws and regulations, etc.). In addition to the Arabic version, an English version of the questionnaire is attached in the appendices, see Annex 1 & 2.

3.5 Statistical Analysis

The data collected from interviewed farmers was analysed using Statistical Package for Social Science software, SPSS, and the results were quantitatively presented. The number of the interviewed farmers was determined upon the start of the research to cover the whole sample space of 44 users of the TWW in Jenin. Previous information demonstrated that the sample space contained more than 60 farmers. After having contact with the farmers, around 20 farmers were eliminated from the list for not being able to experience the reuse of the TWW. One of the reasons was that treated effluent couldn't be pumped to their lands upstream the WWTP. Figure 12 shows upstream (112 m ASL, which is close to the WWTP's elevation, and around 1 km away) and downstream (around 90 ASL and 2-3 km away) agricultural lands that were targeted in the irrigation project with relative to the WWTP.

Figure 12. Up-stream and Down-stream areas with relative to WWTP (GeoMOLG, 2019)

Another reason was that some farmers were enthused to join the formed committee of the farmers but ended up not using the treated wastewater. Falling into the delusion of having above 60 farmers to be included in the study was caused by being introduced to old information. The research was completed anyway. The data were later analysed by a statistician using SPSS as mentioned, then the results were presented and analysed in chapter four.

3.6 Laboratory Water Tests; Collecting and Analyzing

Four laboratory tests for the TWW during the period 2014 to 2020 were provided via N. Atari (Personal communication, August 12, 2022). These tests were added to the Annexes, see Annex 4, then analyzed and discussed in ***section 4.8***. The high value added by analyzing the water quality tests was the providing of a better understanding of the farmers' worries and concerns.

3.7 Ethical Consideration

All data was only collected and presented on a scientific basis and analyzed as a whole. Farmers were interviewed after being informed honestly and specifically about the reasons for which the data collection is meant. Accessibility to data "full questionnaire" is limited to the researcher and his supervisor for academic purposes. Besides, the owner party of the original data is committed not to expose any personal data that is related to the interviewees. The questionnaire's introduction included the subject of the study and informed that the collector of the data is a master student at the Institute of Water and Environmental Studies in Birzeit University collecting the data for his master thesis.

Chapter Four

Results and Discussions

In this chapter, the results of the thesis are shown and discussed in details. Basically, the results were obtained by statistically analyzing the data collected in the interviews with the farmers using SPSS after filling the formed Questionnaire. Nine models were considered in the process of data analysis with an average accuracy of 51%, while the reference model has got an accuracy of 100%. The 44 interviewed farmers were all males, and together they formed the whole sample space. As the previous sentence suggests, no farmers were left out of the sample size and all the applicable farmers who had experience with using wastewater for irrigation in Jenin City were interviewed.

4.1 General Statistics Regarding the Interviewed Farmers and their Farms

Their ages ranged from 21 to 65 years old. With a frequency of 28 out of 44 and a percentage of 63.6%, most of the farmers were middle aged whose ages ranged between 31 and 50 years old. Figure 13 shows the distribution of the ages of the farmers.

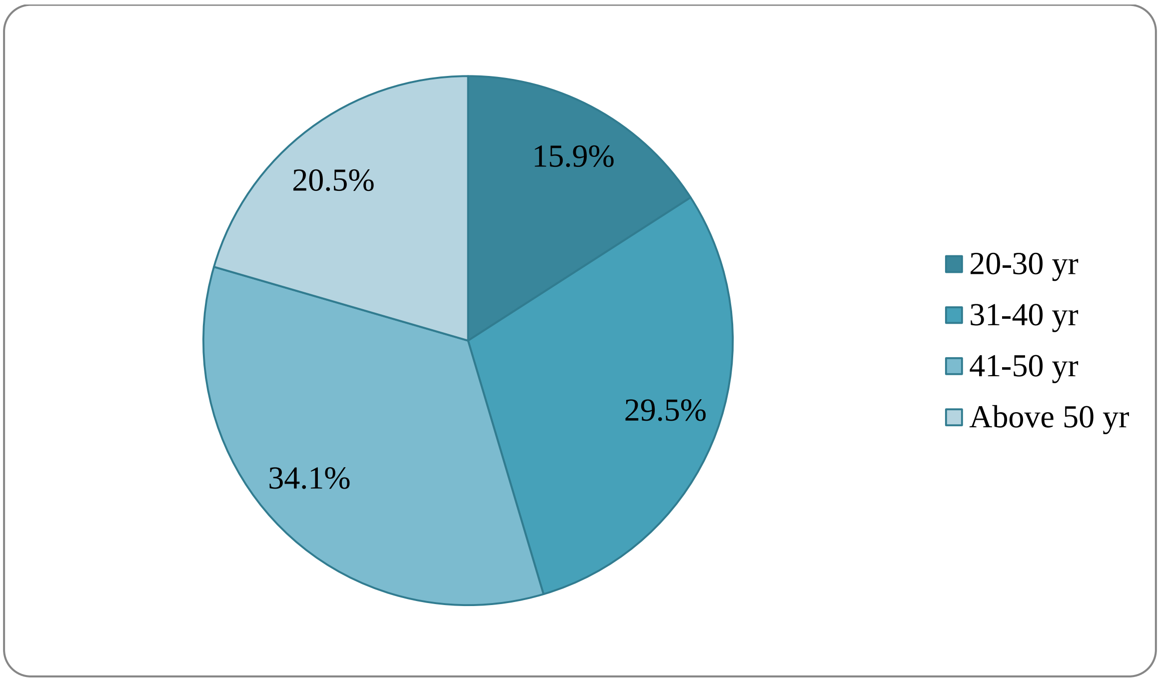

Figure 13. Age categories of the farmers in percentage

56.8% of the farmers practiced agriculture as a major career, while 43.2% of them practiced it as a secondary source of income. This is pretty much similar to what Mizyed (2013) said that, in the community he studied, agriculture was taken as a part time job since it was participating in less than 50% of the total income for around 75% of the farmers interviewed. The aggregate cultivated area irrigated with treated effluent reached 585.5 dunum collectively. Most of the cultivated farms were self-owned, emphasizing Mizyed's (2013) statement that 83% of the farms were cultivated by the owners themselves. The farms ranged from 1.5-50 dunums in area with an average size of 1.33 ha while Mizyed (2013) has also recorded an average size of 1.4 ha. The farms were classified based on area into three ranges; small (less than 1 ha, 10 dunums), medium (between 1 and 3 ha, 10-30 dunum), and large (larger than 3 ha, >30 dunum). 36.4% of the farms were considered small, 59.1% of the farms were considered medium, while only 4.5% of the farms with a frequency of 2 farms exceeded 3 ha in area to be classified as large farms, see Figure 14.

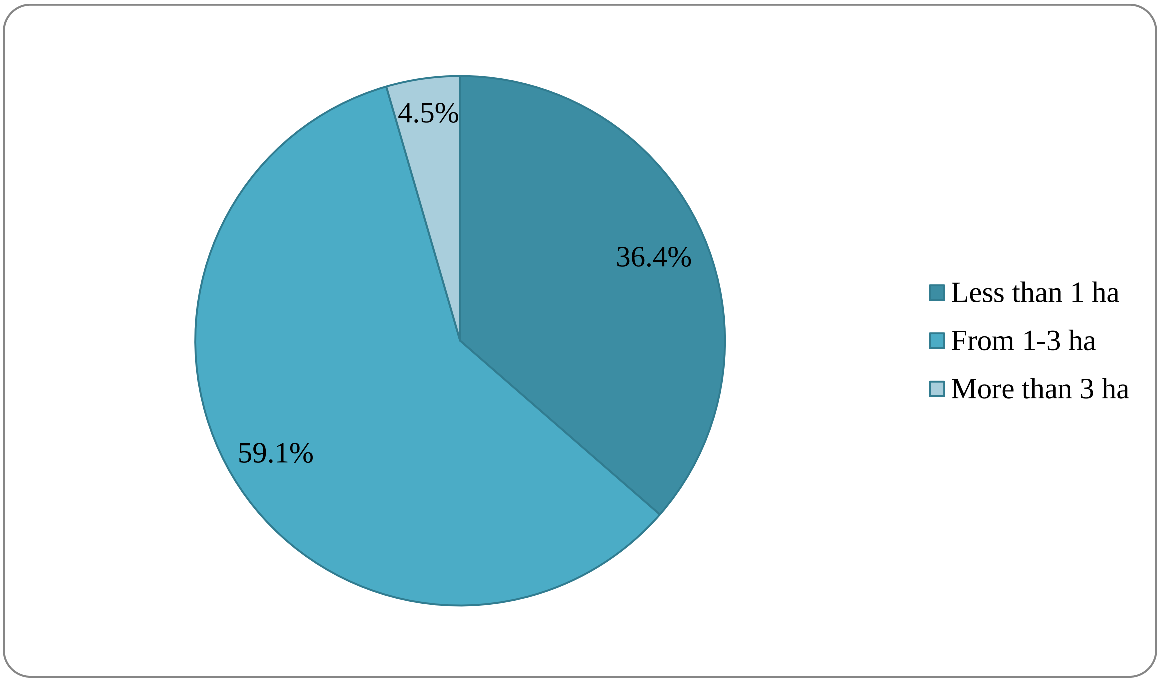

Figure 14. Farms distribution based on area categories

Three farmers used both fresh and treated water in their farms. However, 41 (93.2%) of them only used treated water for irrigation. Two to three labors were sufficient to work in the farm as confirmed by 28 (63.6%) of the interviewees and 91% of them needed less than five labors to run their farms. 5 (11.4%) of the interviewees worked in the farm by themselves needing no additional labors, and only 4 (9%) of the farms had offered job for 5, 6 or 15 labors, see Figure

15. The labors were mostly family and they counted to 132 who cultivated the 585.5 dunums. The average portion of land for each labor was 4 to 5 dunums and it ranged between 0.67 and 15 dunums per labor. 40.9% of the farms were fenced while 59.1% were not, and only 11.4% of the farms were close to housing areas while the remaining 88.6% were far enough from the nearest housing areas.

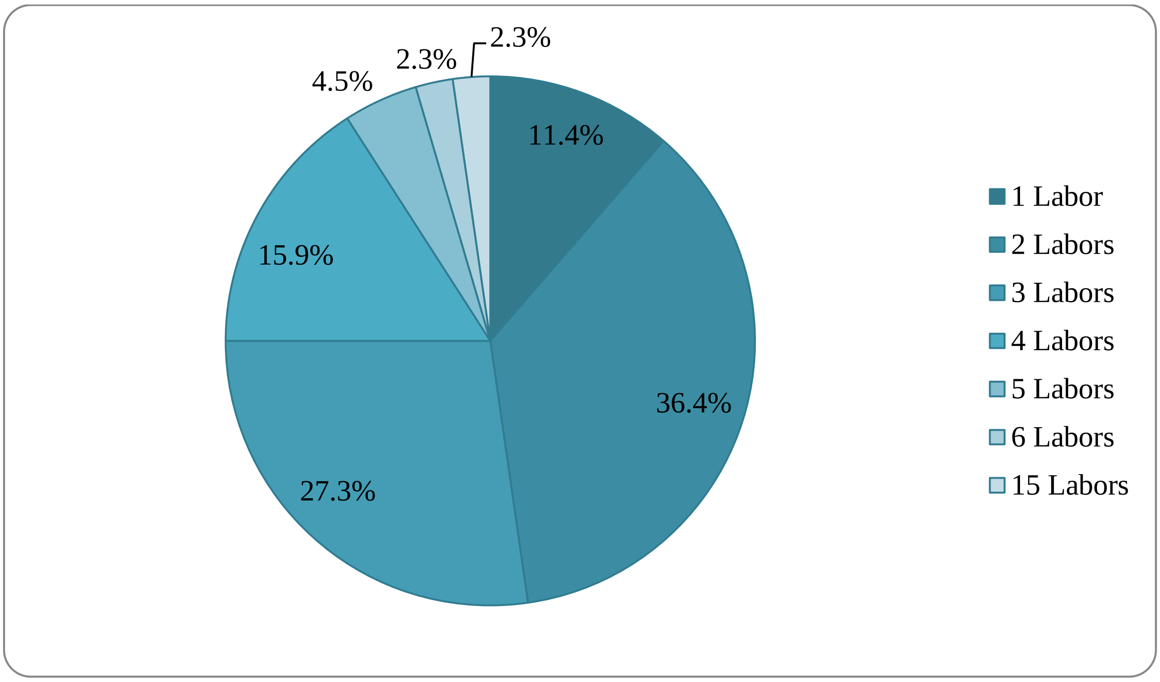

Figure 15. Distribution based on the recruited number of labors to cultivate the farm

The cost of treated effluent was fixed at 0.7 ILS per cubic meter, and the cost of fresh water ranged from 2 to 4 (almost 3 – 6 times the price of TWW) ILS based on the different sources, Figure 16 shows the distribution of the farmers' answers regarding fresh water prices. 59.1% of the farmers had access to fresh water prices between 2.5 & 3.0 ILS, which is +3 times the price of TWW. Surprisingly, only 38.6% of the farmers found the price of the treated effluent satisfying, while the majority represented by 61.4% of them was not satisfied with it and they would pay no more than 0.5 ILS for each cubic meter of the treated effluent. This issue caused an obstacle for the rest of the farmers which is discussed later in this chapter. The irrigation quantities ranged hugely from 5 to 450 cubic meters per dunum per month. The high TWW's quantities exploited by some farmers seemed unreasonable even if the differences in water requirement for different crops were to be considered. Notice that the ***annual*** water requirement for pearl millet, a fodder crop similar to alfalfa, was assumed 365 m^3 /dunum in the study performed by Nassar (2019). Some farmers seemed to exploit larger TWW's quantities than required per dunum. Overabundant quantities of TWW could lead to soil salinization.

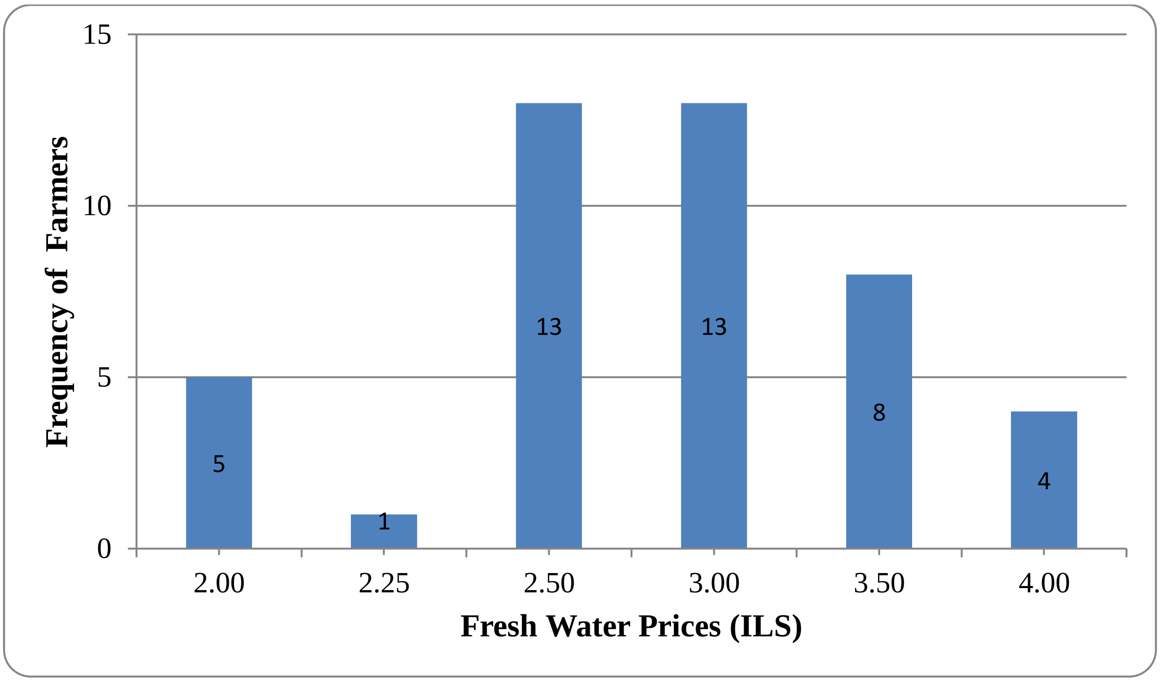

Figure 16. The prices of which the farmers bought their needs of fresh water

86.4% of the farmers finished their secondary education which is very close to the percentage recorded by Mizyed (2013) with a result of 80%. 13.6% of the farmers quit during their mid school while 34.1% of them pursued a college degree after finishing their high school. These results confirm Mizyeds' conclusion that agricultural communities were getting more educated. The degree of awareness and knowledge of the farmers was measured as shown in Table 5.

Table 5 shows the fields of which farmers' awareness is lacking. The future efforts for any awareness and training campaigns should address the weaknesses of the farmers. Mizyed (2013) found that 77% of the farmers didn't know about the Palestinian standards and regulations for TWW reuse as mentioned in ***section 2.10***. Similarly, it was found that 84.1% of the interviewed farmers were not aware of any of these standards. In addition to the Palestinian laws, specifications and TORs, the benefits and the risks of reuse are the fields that should be entitled in the future awareness sessions. It's noticed that the ratio of the trained to the untrained farmers is fifty-fifty. However, except for the farmers' knowledge of risks of reuse, all the answers went to extremes. This could refer to the following factors:

- The farmers are effectively affected by each other in a small community where a right or a wrong idea is easily spread.

- Third the farmers have had collage education and another half of them have finished their high school education, which means that training them clearly have a greater impact.
- Almost three quarters of the farmers were willing to increase their knowledge in the field of reuse. This leads to create a more interactive environment between them.

More training sessions could be held by forming smaller groups of farmers on a picking manner while achieving the maximum benefit of spreading the meant for knowledge in the farmers' community is one of the methods which should be considered in future.

Table 5. Farmers' awareness and degree of knowledge

Question	Percentages of respondents (%)	
	Yes	No
Aware of the environmental benefits associated with using treated effluents in irrigation	27.3	72.7
Aware of the environmental risks associated with using treated effluents in irrigation	52.3	47.7
Aware of the health risks associated with misusing treated effluents in irrigation	100.0	0
Aware of the recommended safety measures for dealing with treated effluents	86.4	13.6
Aware of nutritious content of/within the treated effluents (Nitrogen/ phosphorous/ …) and its effect on the need of using fertilizers	95.5	4.5
Aware of the Palestinian specifications and TORs associated with the wastewater reuse in irrigation	15.9	84.1
Ever been to any training courses related to wastewater reuse	50.0	50.0
Willing to increase knowledge in the field of reuse	72.7	27.3

Just like stated by Mizyed (2013), having a look on the high farmers' awareness in the fields of health risks, safety measures, and the nutritious content of TWW (100%, 86.4%, and 95.5% respectively) confirms a high self-conscious agricultural community which is capable, with proper supervision and additional guiding, of performing the necessary safety measures for public health protection.

4.2 Farmers' Practices

Treated wastewater is used in Jenin City for the irrigation of alfalfa crops and fruitful trees. Only two of the interviewees grew both alfalfa crops and trees in their farms. 13 out of 44 (29.5%) grew fruitful trees only and 29 out of 44 (65.9%) grew alfalfa crops only. These findings go along with the recommendation of the Palestinian MoA to benefit from TWW in irrigating fodder rather than olive trees (Mizyed, 2013; Nassar, 2019). In contract, in Mizyed's (2013) study, 72% of the farmers were willing to use TWW in growing fruit and olive trees while only 20% of them showed interest in growing fodder on TWW.

The percentage of farmers who didn't use any type of fertilizers reached 59.1%, and 36.4% of them relied on some manufactured nutrients without mixing it with natural fertilizers. However, 16 out of the 44 interviewed farmers kept using the same quantity of fertilizers they used to use before turning to the usage of treated effluents in their farm. The rest of them either reduced their usage or completely stopped fertilizing their crops. More information is shown in Tables 6 and 7.

Table 6. Current Usage of Fertilizers

Type of fertilizers	Frequency	Percent
Natural	1	2.3
Manufactured	16	36.4
Both	1	2.3
No fertilizers used	26	59.1
Total	44	100

Table 7 shows the alteration of fertilizers' usage after turning towards using treated effluents by the farmers in their farms. It is noticed that no farmers increased the usage of fertilizers in their farms and around 63.6% of the farmers either reduced or even totally stopped using them. These realistic findings of the farmers' practices reflect the level of knowledge the farmers had and the impact of training and guiding them by the side of ANERA's experts.

Table 7. How did the Usage of Treated Water Affected the Usage of Fertilizers

After using treated effluent	Frequency	Percent
Quantity reduced	9	20.5
Quantity increased	0	0
Same quantity	16	36.4
Stopped using fertilizers	19	43.2
Total	44	100

The most used irrigation system was subsurface drip irrigation (SSDI) with 65.9%. Two farmers used free surface irrigation, while surface drip irrigation (SDI) came second with 29.5%. M. Naeem (Personal communication, January 20, 2020) ensured to us that the farmers who grew alfalfa were guided to use sprinklers for a limited period at the begging of the project, since SDI is not effective for the germination of the seeds. When the roots of the alfalfa crop reached an appropriate depth, the SSDI system was inserted for the irrigation process in all the fodder farms. On the other hand, the farmers who grew trees were guided to rely on SDI. Only three farmers claimed no contact at all with treated water, which leaves 93% of them who ensured the continuous, direct contact with treated water. Therefore, safety measures such as wearing; gloves, gumboots, masks, and plastic suits were taken by the farmers to minimize the risks. Refer to Table 8 to see how gumboots and gloves are the major safety measures considered by farmers.

Table 8. Statistics of Farmers Wearing Safety Equipment

Safety equipment	Frequency	Percent
Gumboots	30	68.2
Gloves	18	40.9
Plastic suits	4	9.1
Masks	3	6.8

The farmers were asked if they have noticed any disease on plants, animals, or men. Six farmers reported signs of disease on plants while no effects on animals or men were reported. Two farmers stepped out of business before any crop harvesting. Hence, when the farmers were asked whether they are taking into account a separating time of period between the last irrigation and the harvest day of their crops or not, 42 of them responded and only five of them kept on the irrigation process until the last day. All five of them grew fruitful trees with the claim that fruits should remain fresh that way. The farmers who adopted the separation strategy were categorized into four categories based on the period; from one to seven days, less than two weeks, less than three weeks, and more than three weeks. The first category included 19 out of 37 representing 51.4% of the valid interviewed farmers. The rest is shown in Table 9.

Table 9. Separating period between last irrigation and harvest day

Period	Frequency	Percent
Less than a week	19	51.4
Less than two weeks	11	29.7
Less than three weeks	2	5.4
More than three weeks	5	13.5

Only 6 farmers (13.6%) responded that they would take safety measures on harvest day without mentioning any. Out of the 13 farmers who grew fruitful trees, ten farmers (76.9%) didn't consider picking up the falling fruits off the ground, while three of them (23.1%) did consider that- two of whom even didn't stop irrigating their trees until the harvest day. On the other hand, all the fodder growing farmers abstained from selling their crop before drying it.

Varied from 5 months of the year to 9 months of the year, 26 (59.1%) of the interviewed farmers used the treated water for six continuous months and 12 (27.3%) used the treated water for seven months as shown in Table 10. All of the interviewed farmers relied on rain water in the rest of the year, see Table 10.

Table 10. The number of months per year during which the farmers used treated water in their farms

Months per year	Frequency	Percent
Five	3	6.8
Six	26	59.1
Seven	12	27.3
Eight	1	2.3
Nine	2	4.5

Only one user of the treated effluent labeled his product as irrigated with treated water, leaving 97.7% of them selling their crops without any labels or any other notation referring to their crops being irrigated with treated water. All of the fodder growing farmers claimed that their customers had the previous knowledge that they are buying treated water irrigated fodder.

Having in their minds that the Israeli fruits irrigated with treated water is sold in the Palestinian markets non-labeled; the fruit growing farmers confirmed the previous claim. It is worth mentioning that there are no such Palestinian forcing laws in that regard.

4.3 Official Supervision

37 farmers (84.1%) reported having their farms being visited by official supervisors and 38 of them (86.4%) experienced the implementation of sanctions by the authorities on people they knew whenever they violated the Palestinians regulations. Some of these sanctions were; imprisonment, financial penalties, and ruining the crop. The farmers were asked about supervision on three levels; water, plant and soil. They were also asked to determine the frequency at which the samples were taken as well as the parties responsible for taking all the deferent samples, refer to Tables 11 and 12. The farmers were asked if they had any reports of the performed tests and none of them actually had any.

Table 11. Farmers' Feedback on the Official Implementation of Supervision on Water, Plant and Soil

Category	Yes Frequency (percent %)	No Frequency (percent %)
Water	29 (65.9)	12 (27.3)
Plant/crop/fruit	19 (43.2)	25 (56.8)
Soil	25 (56.8)	19 (43.2)

As expected, water is supervised more than the other two since 65.9% of the farmers confirmed the water being supervised and regularly tested. 42% answered that water samples have been taken monthly. However, the majority of the answers ensured that testing samples for plants and soil have not been taken yearly. 73.7% and 64% of the valid answers for plant and soil, respectively, reinforced the previous claim. In most cases, the samples were taken by governmental parties, see Table 12.

As shown in ***section 4.4***, the farmers expressed their resentment at being abandoned and ignored by the official parties due to the weak role played by these governmental parties, as well as their distrust in the WWTP's operators not doing their job to assure the water quality. Eventually, that weakened their trust of the water quality since they started to realize some of its side effects on their irrigation systems, soil and other aspects. On the other hand, experts and officers of MoA, ANERA, and Jenin's WWTP confirmed the validity of TWW for agricultural reuse. Communicating with the farmers and increasing their accessibility to periodical laboratory reports of the quality of water, plant and soil are recommended tools to regain the farmers' trust and loosen their intense position from the official parties and the water quality.

Table 12. Determination of frequencies of taking samples and the parties responsible for that by the farmers who ensured the supervision on water, plant and soil

Sample taking frequencies and parties performing them		**Water**	**Plant and crop**	**Soil**
Frequency of taking samples	Once per month	11 (42.3%)	-	-
	Once in three months	6 (23.1%)	-	-
	Twice per year	1 (3.8%)	2 (10.5%)	3 (12%)
	Once per year	5 (19.2%)	3 (15.8%)	6 (24%)
	Not every year	3 (11.5%)	14 (73.7%)	16 (64%)
Party responsible for taking samples	Governmental parties	21 (72.4%)	17 (89.5%)	23 (92%)
	Supervisors from wastewater treatment plant	2 (6.9%)	-	-
	Agricultural institutions and associations	6 (20.7%)	2 (10.5%)	1 (4%)
	Farmer taking samples himself	-	-	1 (4%)

4.4 Motives, Obstacles and Worries

One of the most important subjects of the study was to seek the motives and the obstacles that led the farmers or handicapped their entrance to the field of using treated effluent for irrigation in their farms. The questionnaire included 18 factors which were seen as motives, obstacles, or neither by the interviewed farmers. The study pointed out to the most influential factors amongst those and discussed them. These factors are:

1. Availability of fresh water for irrigation.
2. Treated water price.

3. Concern for environment (groundwater, wild life, …).
4. Concern for health impacts.
5. Marketing.
6. Effect on crop quality.
7. Effect on soil.
8. Degree of experience in the field.
9. Success or failure of a known pilot project.
10. Incentives by the government.
11. Government commitment towards farmers by guiding, supervising and training them.
12. Type of crop growing in the farm (trees or alfalfa crops).
13. Degree of trust in the supervision on treated water quality by wastewater plant.
14. Farm's site (close to or far from housing areas or the treatment plant).
15. Awareness campaigns.
16. Irrigation project funding in the region.
17. Religious worries.
18. Psychological worries (disgust).

The results of investigating the farmers' views about the 18 factors are exhibited in Table 13 (parts A, B, and C; six factors in each sub-table). After the data was analyzed, it was found that the farmers tended to be more motivated than hindered by those factors. The analysis was done by adding the percentages corresponding to each answer solely (motive, obstacle, or neither) and dividing the answer by 1800% (18 factors x 100%) like follows:

$$Motive\ Index = \frac{(3*2.3+2*6.8+15.9+25.0+36.4+61.4+65.9+68.2+77.3+81.8+97.7+100)\%}{1800\%}$$

$Motive\ Index$ = 650.1/1800

$Motive\ Index$ = 0.361
$Obstacle\ Index$ = 0.308
$Neither\ Index$ =0.331

The summation of the three indices is equal to one. Clearly the highest index is the *motive index* of 0.361, and the lower index is the *obstacle index* which confirms the previous result of the farmers showing to be more motivated or at least less affected (since the *obstacle index* is also below the *Neither index*) than hindered by the factors set for this study. ***The establishing of <u>the irrigation project</u> by the American Near East Refugee Aid (ANERA) association was the*** *primary force* ***that drove the farmers towards the reuse and spread of the acceptance of the idea amongst Jenin's farmers***. The seventh pond was added in Jenin's WWTP by ANERA to be the station of which the treated water is pumped to the agricultural lands of the farmers.

Moreover, ANERA equipped the treatment plant with gravel filters, pumps, chlorination system, and a conveyor treated water line that connects between the treatment plant and the targeted agricultural lands of the plains. ANERA went even further when they decided to fund the reuse project in Jenin City. ANERA then introduced the farmers to the reuse business through consecutive sessions then subsidized them to start their own reuse business. Afterwards, ANERA imported the saplings and the seedings of the kinds that are irrigated with treated effluents from different destinations around the world. Eventually, ANERA helped establishing the farmers' reuse association and supervised on them and performed several tests on the treated water to investigate its quality for reuse. The results of these tests ensured the viability of the outflow in Jenin WWTP to be reused in agriculture (M. Naeem, Personal communication, January 20, 2020), regarding the results of the tests, see ***section 4.8.***

Having that in mind, the 44 interviewed farmers considered the establishing of an irrigation project to be the cornerstone for any reuse project in the future. The second most important driving factor was the price of TWW compared to the fresh water prices since only one farmer wasn't attracted to it. Respectively, 81.8% and 77.3% of the farmers voted for "type of the crop they used to grow in their farms" and "pilot project success" in the third and fourth places as the most essential motivating factors. It's worth mentioning that ANERA planted alfalfa crops as a pilot project in a specific land which was presented by one of the volunteering farmers, and the results were great. Type of crop planted in the farms mostly affected the decision of the farmers who planted alfalfa crops. These farmers used to cultivate their lands only once every year at the ending of the winter season. The alfalfa crop of the pilot project was harvested every three weeks in the summer gaining huge financial profits.

Initiating and funding an irrigation project have two sides of support to it; financial support and expertise, which comes in terms of guiding and experience transfer. TWW's price is considered purely financial while type of crop cultivated by the farmers measures their experience. Finally, success of a pilot project reflects both; feasibility and experience. Farmers seem to show interest in a particular investment when its feasibility is proved while having the required experience or sufficient guidance to run it.

Availability of fresh water, site of the farm with reference to the nearest housing areas, and incentives presented by the government came later in the list. 31.8 % of the farmers didn't consider the scarcity of fresh water to be severed and claimed that they can still buy it as a resort **whenever the quality of the TWW deteriorates significantly**. It is widely known that water prices go down when water availability increases. It is also understood that TWW is less reused in agriculture when the price gap gets closer and closer with fresh water. The fact that not even one of the interviewed farmers has seen the fresh water availability factor as an obstacle for reuse means that none of them has actually considered it as an alternative source of water yet, confirming the high gap in prices presented is ***section 4.1***, or in other words, the suitability of TWW's price at 0.7 ILS compared to the high prices of fresh water. Ultimately, this ensures the water scarcity in the plains of the city.

The farmers' WTP in Jordan and Tunisia in the study performed by Abu Madi *et al.* (2003) didn't exceed 0.05 US $\$/m^3$ (< 0.2 ILS). According to Abu Madi *et al.* (2003), the two major obstacles that prevented the farmers from using TWW unless its price is as low as 0.05 US $\$/m^3$ were water abundance and their distrust in the water quality. In short, Farmers' WTP is decreased or increased according to fresh water availability, TWW's quality, and the price gap between FW and TWW. Proportionally, the two gaps between TWW and FW, quality gap and price gap, can change the farmer's stance toward exploiting TWW in irrigation. The higher the quality gap is, the higher the price gap required by the farmer in order to be driven in the direction of reuse. Raising the quality of TWW or lowering its price significantly would break the disgust barrier. The community's perception of consuming crops which are irrigated with RW can also affect the farmer's mentality and increase his WTP for RW as proven by Menegaki, *et al*. (2007). According to Menegaki, *et al*. (2007), in Crete, farmers were willing to pay for RW at 55% the price of FW since the consumers were willing to consume their product at 88% of its current market price.

The main obstacles and worries the farmers faced before entering the field of reuse were; disgust (68.2%), the fear of the bad supervision on the treatment process and the quality of the produced TWW by the labors of the treatment plant (68.2%), the fear on their health when dealing with a water source that is seen as pathogenic (63.6%), the worries of the side effects on the soil of their farms (63.6%). One of the farmers stopped using the water after observing some of the side effects on the soil of his land. According to him, it took the soil two years of rehabilitation to recover from those side effects. Religious worries and the lack of experience came fifth and sixth in the list of obstacles with percentages of (56.8%) and (54.5%), respectively, see Table 13.

Table 13 - part A. Farmers' response towards motives and obstacles before using the treated water

Farmers' views in percentage (%)	Fresh water availability	TWW price	Concern for environment	Concern for health impacts	Marketing	Effect on crop quality
Motive	68.2%	**97.7%**	15.9%	2.3%	6.8%	6.8%
Obstacle	-	2.3%	18.2%	**63.6%**	31.8%	27.3%
Neither	31.8%	-	**65.9%**	34.1%	**61.4%**	**65.9%**

Table 13 - part B. Farmers' response towards motives and obstacles before using the treated water, contd.

Farmers' views in percentage (%)	Effect on soil	experience	Pilot project success	Incentives by government	Guiding & supervising by government	Type of crop
Motive	-	2.3%	**77.3%**	61.4%	36.4%	**81.8%**
Obstacle	**63.6%**	54.5%	2.3%	20.5%	38.6%	-
Neither	36.4%	43.2%	20.5%	18.2%	25.0%	18.2

Table 13 - part C. Farmers' response towards motives and obstacles before using the treated water, contd.

Farmers' views in percentage (%)	Degree of trust in supervision	Site of the farm	Awareness campaigns	Irrigation project	Religious worries	Disgust
Motive	25.0%	65.9%	2.3%	**100%**	-	-
Obstacle	**68.2%**	4.5%	34.1%	-	56.8%	**68.2%**
Neither	6.8%	29.5%	**63.6%**	-	43.2%	31.8%

The following factors were seen as the least important according to the farmers and were neither considered motivating nor hindering by the majority of them:

1. Effects on environment (65.9%).
2. Effects on crop quality (65.9%).
3. Awareness campaigns targeting the consumers of the reuse products (63.6%).
4. Marketing (61.4%).

These factors reflect the selfish side of the farmers who feel threatened by researchers and official supervisors. They are willing to sell their products blindly without informing their costumers of the fact that their products are irrigated with reused water. They prefer to turn a blind eye to the potential side effects their practice would leave on the environment or the crop quality. The minority of the farmers has seen the bright side of reuse in light of environment, health, crop quality, and costumer awareness. This group of farmers has truly understood and shown good understanding of the benefits of treatment and reuse when the delivered water is well treated and achieving the standards and the specifications for reuse.

According to this category of farmers, treatment and reuse are more beneficial to the environment and human health than discharging raw wastewater into the rivers and valleys. They also visualize the awareness campaigns targeting costumers and markets to be the right thing to do. They are not worried about losing their business if these campaigns were well organized to convince society of the truth that these products are not harmful, and they were even willing to stop using TWW if future studies proved that using it can cause harm to health, plant, or the environment. This mentality is encouraged to be spread in the farmers' community

On the second part of seeking motives and worries, the farmers were asked about the current worries and concerns they had (the worries which were arisen from their experience in dealing with treated wastewater). The shifting in their mentalities was more obvious in some fields than others, while three farmers didn't have any concerns at all. For example, the price of treated water was previously seen as a driving factor and only one farmer showed to be concerned about it, see Table 13. After buying TWW for irrigation, 63.4% of the farmers started to express their objection on the price, see Table 14. The reason behind that could refer to the changing water quality up and down according to the farmers. Nevertheless, this could refer to the huge and exaggerated quantities demanded by the fodder growing farmers, in particular, as well as accumulating the bills of electricity instead of paying them on a regular basis with each harvest. The justification for that conclusion is that the farmers who grew fruitful trees seemed to be more satisfied than the fodder farmers regarding water price and water quality, considering the higher potential of direct contact with TWW in the case of trees growing farmers.

They asked for lowering the price from 0.7 ILS to less than 0.5 ILS. Some of them went even further by suggesting the idea of delivering them the water for free instead of wasting it in the Wadi and enduring a higher cost that is paid to the Israeli government. Later on, the huge electricity bills were left unpaid and the electricity company frequently cut off the supply of electricity to the farmers' association. Eventually, many farmers stepped out of business. The issue with the electricity company is discussed more in ***section 4.7***.

Table 14. The worries and concerns the farmers had after using the treated water

	TWW price	Concern for the environment	Negligence on the part of the government	Distrusted water quality	Marketing	religious worries	Disgust
An obstacle	63.4%	17.1%	68.3%	90.2%	0.0%	39.0%	41.5%
Not an obstacle	36.6%	82.9%	31.7%	9.8%	100.0%	61.0%	58.5%

The concerns for marketing and environment were still seen unimportant by the farmers representing the lowest affected aspects amongst all. On the other hand, the farmers have significantly changed their way of thinking towards both psychological (disgust) and religious worries in the direction of removing them from their "obstacles list". Previously, disgust and religious prohibition were categorized as obstacles by the majority of the farmers, dissimilar to what the study of Abu Madi *et al*. (2003) concluded as the percentages of the farmers who felt unsure or totally rejected to deal with RW due to disgust or religious prohibition were below 30%. However, after dealing with TWW, the farmers who still had difficulties dealing with TWW in terms of disgust or religious reasons fell below or around 40%, closing the gap with what Abu Madi *et al.* (2003) had concluded.

The remarkable deterioration in water quality, according to the interviewed farmers, and the noticeable absence of the government from the picture were sufficient to remind the farmers of the importance of the roles that should be played by the official parties of the government and the supervisors of the treatment plant. Therefore, 90.2% of the farmers expressed their discontent with the supervisors of the WWTP for the bad water quality that was delivered to them to be considered the major obstacle the farmers had to face. The farmers expressed the bad quality of TWW in terms of color, smell, and frequent blockage of irrigation systems. 68.3% of the farmers expressed their concerns towards the lack of interest from the side of the government to supervise, fund and guide them, while only 38.6% of them were hindered by the pale role of the government in the beginning of the reuse project. The worries of the farmers were ranked from the most to the least significant as follows, see Figure 17:

1. Bad water quality (90.2%).
2. Negligence on the part of the government (68.3%).
3. The high price of TWW (63.4%).

4. Psychological worries (disgust), (41.5%).
5. Religious worries of prohibition (39.0%).
6. Concern for environment (17.1%).
7. Marketing (0.0%).

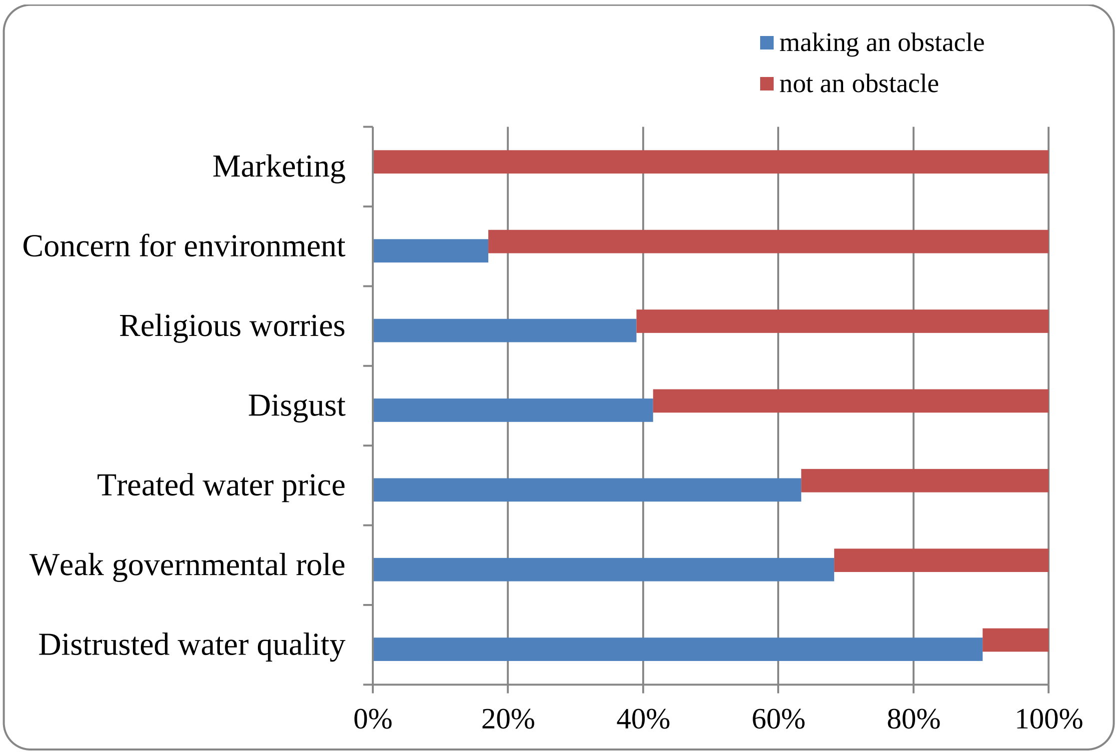

Figure 17. Worries and concerns arisen after using the treated water

4.5 The Observed Effects of Using the Treated Effluent as Reported by the Farmers

The farmers were asked about the results and the effects which they have observed and experienced since they started using the treated water in their farms on the following levels:

1. Crop quantity.
2. Crop quality.
3. The increase of insects in the farm.
4. Unpleasant odors.
5. Soil quality.
6. Health.
7. Marketing.
8. Irrigation system.

Leap forward to Table 15 and see the corresponding frequencies and percentages for each aspect. Once again the indices of the three possible answers (positive, negative, no difference) were estimated and compared like follows:

$$Positive\ Index = \frac{(77.3 + 50.0 + 0 + 0 + 4.5 + 0 + 47.7 + 2.3)\%}{800\%}$$

$$Positive\ Index = 0.227$$
$$Negative\ Index = 0.293$$
$$No\ difference\ Index = 0.480$$

The *no difference index* was the largest with a value of 0.480, and the *negative index* was greater than the *positive index*. The highest contributors to the *no difference index* were the impacts on human health (100%), soil quality (56.8%), and the spread of insects (54.5%). The highest negative impacts were seen on irrigation systems and pipes blocking (77.3%), as well as the emission of unpleasant odors (54.5%). The aspects which were affected positively as reported by the farmers were the produced quantities (77.3%), crop quality (50.0%), and the marketing of the agricultural products (47.7%). Figure 18 shows the results distribution of the eight considered aspects versus percentages.

Table 15. The farmers' response towards the observations of the effects of reuse

	Crop quantity	Crop quality	Insects increase	Unpleasant odors	Soil quality	Health	Marketing	Irrigation system
Positive	34 (77.3%)	22 (50.0%)	0	0	2 (4.5%)	0	21 (47.7%)	1 (2.3%)
Negative	3 (6.8%)	2 (4.5%)	20 (45.5%)	24 (54.5%)	17 (38.6%)	0	3 (6.8%)	34 (77.3%)
No difference	7 (15.9%)	20 (45.5%)	24 (54.5%)	20 (45.5%)	25 (56.8%)	44 (100%)	20 (45.5%)	9 (20.5%)

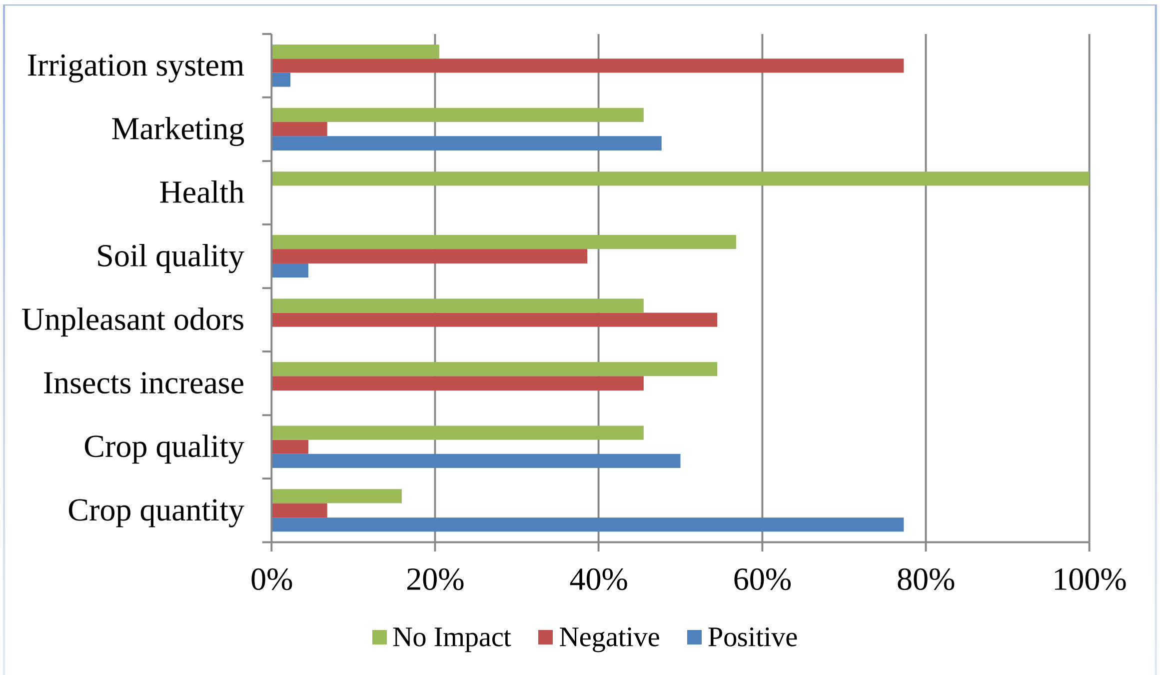

Figure 18. The observed effects (Positive, Negative, No Impact) on the studied aspects caused by using the treated effluent as reported by the farmers

4.6 Studied Relationships

Many relationships were studied in the research, and then the relationships with high correlations were presented and discussed. The independent factors in these relationships were:

- Type of plant the farmers grew in their farms (Tables 16 - 19),
- Farmers' awareness of official supervision (Table 20),
- Farmers' attitudes towards encouraging (or not encouraging) other farmers to start using the TWW (Table 21),
- Whether the farmer has received any training related to dealing with treated water (Table 22),
- and, Age (Table 23).

Type of plant grown by the farmers (trees or alfalfa crops) was the most distinguishing factor of the mentalities of the farmers amongst all and had high correlations with the farmers' practices, worries, commitment to following safety measures as well as their feedback on the effects of using TWW in their farms.

Farmers' awareness of being supervised upon was found to have strong relationships with the behaviors of not mixing fresh water with treated wastewater, not wearing flu masks, and not observing any kind of disease on plants. Besides, the highest percentage of the farmers who were still using the treated wastewater encouraged new farmers to enter the business.

Regarding training consequences, trained farmers showed higher awareness of environmental risks and safety measures which were recommended to be followed when dealing with treated wastewater. On the other hand, the untrained farmers showed more ignorance about environmental risks and the knowledge concerning safety measures, so they were less committed to abide by those safety measures. The results connecting age and awareness of the environmental benefits of reuse were interesting. Age was also highly correlated to the consideration of the used system of irrigation and the separation period between irrigation and harvest day.

All the relationships mentioned above passed the null hypothesis test with P-value < 0.05, which means that the probability of the null hypothesis being true is less than 0.05 and the probability of the alternative hypothesis being true is above 0.95, indicating a statistically significant relation and a strong correlation. It should be known that **the null hypothesis** is “a typical statistical theory which suggests that no statistical relationship and significance exists in a set of given single observed variable, between two sets of observed data and measured phenomena” (Haldar, 2013).

Table 16 shows the correlation between the type of plant grown by the farmers and their level of satisfaction. All the farmers growing alfalfa crops had their own worries after using the TWW in their farms as well as 76.9% of the farmers growing trees. However, none of the farmers growing alfalfa has reported any signs of disease on the crop, while 38.5% of the trees growing farmers have observed some of those signs. On the other hand, the farmers growing fruitful trees showed a higher rate of satisfaction (84.6%) towards the TWW’s price since 90% of them haven’t seen the current price to be an obstacle, while 79.3% of the fodder growing farmers have considered the current price an obstacle and were not satisfied with it.

Table 16. Variation in farmers' response based on the type of plant they grow and their satisfaction, worries, and obstacles

Question	Answer	Percentage of respondents (%)		
		Fruitful trees	Alfalfa crops	Both
Worries after using TWW? P-value=0.022 chi-square=7.677, df=2	Yes	**76.9 (22.7)**	**100 (65.9)**	**100 (4.5)**
	No	23.1 (6.8)	0	0
Satisfied with TWW' price? P-value=0.000 chi-square=16.791, df=2	Yes	**84.6 (25.0)**	20.7 (13.6)	0
	No	15.4 (4.5)	**79.3 (52.3)**	**100 (4.5)**
Is TWW's price considered an obstacle? P-value=0.000 chi-square=16.610, df=2	Yes	10.0 (2.4)	**79.3 (56.1)**	**100 (4.9)**
	No	**90.0 (22.0)**	20.7 (14.6)	0
Any diseases observed on plants? P-value=0.001 chi-square=13.628, df=2	Yes	38.5 (11.4)	0.0	50.0 (2.3)
	No	**61.5 (18.2)**	**100 (65.9)**	50.0 (2.3)

*number in brackets () represents the percentage from the whole sample while the number before brackets () represents the percentage in the column only, this applies to all tables from 16 – 23.

It should be concluded that except for olive trees, the farmers growing fruitful trees used to irrigate those trees with fresh water before they were introduced to using TWW, or at least had the common knowledge that the majority of fruitful trees are categorized within the irrigated agricultural kinds. However, the fodder growing farmers have been relying on rain-fed types of fodder plants and then found it hard to pay for the irrigation water after shifting to alfalfa irrigated with TWW.

Table 17 shows the correlation between the type of plant grown by the farmers and some of their practices. The majority of the interviewed farmers relied only on TWW without mixing it with fresh water from time to time as recommended by ANERA's expert excluding three farmers who relied on both treated and fresh water; two of them grew only trees and the third grew both trees and alfalfa. In the same contest, most of the farmers from both sides (fodder growing farmers and trees growing farmers) representing 59.1% of the whole sample used the TWW in six months yearly and relied on rainfall during the rest of the year. The high correlation between type of plant and the used of irrigation system was logical and clear with a **P-value = 0.000**, since 84.7% of the farmers growing trees relied on SDI and 93.2% of the alfalfa growing farmers relied on SSDI. Both parties of farmers showed a high commitment to the guidance provided by ANERA's experts regarding the use of irrigation systems as indicated in ***section 4.2***.

Table 17. Variation in farmers' response based on the type of plant they grow and their practices

Question	Answer	Percentage of respondents (%)		
		Fruitful trees	**Alfalfa crops**	**Both**
Type of water used in irrigation P-value=0.009, chi-square= 9.493, df=2	Only fresh water	0	0	0
	Only treated water	**84.7 (25.0)**	**100 (65.9)**	50.0 (2.3)
	Both	15.3 (4.5)	0	50.0 (2.3)
Type of irrigation system used in the farm P-value=0.000 chi-square=35.914, df=4	Sprinkler irrigation	0	6. (4.5)	0
	SDI	**84.7 (25.0)**	0	**100 (4.5)**
	SSDI	15.3 (4.5)	**93.2 (61.4)**	0
	Surface irrigation	0	0	0
How many months is the treated effluent used yearly? P-value=0.0171 chi-square=14.432, df=8	5	15.3 (4.5)	3.5 (2.3)	0
	6	**46.1 (13.6)**	**65.5 (43.2)**	50.0 (2.3)
	7	30.8 (9.1)	27.6 (18.2)	0
	8	0	3.5 (2.3)	0
	9	7.8 (2.3)	0	50.0 (2.3)

All the farmers growing trees have fenced their farms while 89.7% of the alfalfa farmers have not, see Table 18 which presents the correlations between type of plant and the farmers' commitment to safety measures. The farmers who grew trees expressed their fears having an unfenced farm considering the possibilities for an unauthorized entrance by strangers and especially kids. The facts that these farmers used SDI and grew fruitful trees would always leave the potential for either a direct contact with TWW or picking up a falling fruit off the ground. On the other hand, the fodder farmers didn't have any of those fears since they used SSDI systems and grew fodder crops instead of fruitful trees.

Table 18. Variation in farmers' response based on the type of plant they grow and their commitment to safety measures

Question	Answer	Percentage of respondents (%)		
		Fruitful trees	**Alfalfa crops**	**Both**
The existence of a fence P-value=0.000 chi-square=32.874, df=2	Yes	**100 (29.5)**	10.3 (6.8)	**100 (4.5)**
	No	0	**89.7 (59.1)**	0
Wearing flu masks P-value=0.022 chi-square=7.677, df=2	Yes	23.1 (6.8)	0	0
	No	**76.9 (22.7)**	**100 (65.9)**	**100 (4.5)**
Is irrigation stopped before harvesting? P-value=0.002 chi-square=12.961, df=2	Yes	**63.7 (16.7)**	**100 (65.9)**	50.0 (2.4)
	No	36.3 (9.5)	0	50.0 (2.4)
Period of separation P-value=0.000 chi-square=25.149, df=6	Less than a week	28.6 (5.4)	**58.6 (45.9)**	0
	1-2 weeks	0	37.9 (29.7)	0
	2-3 weeks	14.3 (2.7)	3.4 (2.7)	0
	3 weeks or more	**57.1 (10.8)**	0	**100 (2.7)**
Any safety measures on harvest day P-value=0.000 chi-square=15.644, df=2	Yes	45.4 (11.9)	0	50.0 (2.4)
	No	**54.6 (14.3)**	**100 (65.9)**	50.0 (2.4)

Table 18 also shows that none of the fodder farmers wore flue masks while only 23.1% of trees growing farmers did, mainly to avoid the smell they had to deal with from time to time emitting from the TWW on the soil surface. It's worth mentioning that flue masks were recommended in the first place for the fodder growing farmers at the first stage of the project due to using sprinklers to assure the roots' germination of the seeds. The alfalfa farmers, all of them, stopped irrigating their crops before harvesting from 1-7 days (58.6%) up to two weeks (37.9%). According to them, it was necessary to harvest their farms when the ground was dry, and they all reported that fodder was dried before being sold. The results of tree growing farmers on the separation period question are not reliable and it is pointless to discuss them. The reason for that refers to the fact that a good portion of them couldn't grow their trees to the point of fructification before stepping out of business. Even those who made it to that point have confirmed that in order to get fresh fruits, trees should be irrigated until the last day before harvesting. However, trees could just be irrigated with fresh water instead of TWW a week or two before harvesting, which was not the case for those farmers, or just relied on precipitation considering the season of harvesting for some types of trees. Besides, some farmers stopped using TWW when their trees became fruitful and started to rely on fresh water instead. Moreover, 45.4% of the farmers growing trees claimed to follow some safety measures on harvest day without mentioning any of them, which is again not a reliable result to discuss due to the same previous reasons, considering the fact that three farmers did consider picking up the falling fruits off ground. On the other hand, all the fodder growing farmers agreed that no safety measures were consider on the day of harvesting. Table 18 shows the consistency of ideas amongst the fodder growing farmers in the same contest of the previous results throughout the chapter compared to the eccentricity of thinking amongst the trees growing farmers.

Table 19 shows the variation in farmers' response based on type of plant and the effects observed by the farmers on **crop quantity, crop quality and marketing**. On all three aspects, the highest percentage of farmers growing trees could not recognize any impact of using TWW. 38.6% of them reported a positive impact on crop quantity compared to 15.3% who found the impact to be negative, while 23.1% of them reported a positive impact on crop quality compared to 15.3% who actually reported a negative impact on quality. Besides, 15.3% of them struggled with marketing their products, while 84.7% didn't find irrigating with TWW to have any impact on marketing at all.

On the other hand, the farmers who planted alfalfa crops reported a high positivity of using TWW on **crop quantity, crop quality and marketing.** Except for one farmer who reported a negative impact, all the fodder growing farmers observed a positive impact on crop quantity. As stated before, this refers to the local types of fodder crops being rain-fed which were only cultivated once, maybe twice, per year compared to a three-week circle of cultivation for alfalfa during summer. However, no straightforward relationship was found between TWW and crop quantity. This kind of relationship can only be proved and tested after fixing all the variables in two farms including the type of the cultivated crop, one irrigated with TWW and the other one irrigated with fresh water. When asked about the effects on crop quality, 65.6% of the fodder growing farmers reported a positive impact compared to 34.4% who didn't report any effect on quality. This result is also questioned due to the shifting from local types to alfalfa.

With regard to marketing, 72.4% of this party of farmers reported a positive impact compared to 27.6% who didn't report any impact at all. According to them, the continuity of producing alfalfa fodder throughout the summer made them a reliable source of fodder to the livestock keepers especially horses.

Table 19. Variation in farmers' response based on the type of plant they grow and their observations of the effects

Question	Answer	Percentage of respondents (%)		
		Fruitful trees	Alfalfa crops	both
Effect on crop quantity	Positive	38.6 (11.4)	**96.5 (63.6)**	50.0 (2.3)
P-value=0.001	Negative	15.3 (4.5)	3.5 (2.3)	0
chi-square=19690, df=4	No impact	**46.1 (13.6)**	0	50.0 (2.3)
Effect on crop quality	Positive	23.1 (6.8)	**65.6 (43.2)**	0
P-value=0.018	Negative	15.3 (4.5)	0	0
chi-square=11.867, df=4	No impact	**61.7 (18.2)**	34.4 (22.7)	**100 (4.5)**
Effect on marketing	Positive	0	**72.4 (47.7)**	0
P-value=0.000	Negative	15.3 (4.5)	0	50.0 (2.3)
chi-square=26.140, df=4	No impact	**84.7 (25.0)**	27.6 (18.2)	50.0 (2.3)

The variation in the extent of farmers' response based on awareness of the official supervision showed a close correlation ensuring the deep impact of supervision on farmers' behaviors and practices. The answers of the farmers went to extremes (+90 ~ 100%) when they felt being supervised. Respectively, when asked about the type of water used in the farm, wearing a flue mask, and observing potential symptoms of disease on plants, the responses went from (71.7%, 71.7% and 57.2%) for the farmers not being supervised up to (97.3%, 97.3% and 91.9%) for the farmers who were aware of the official supervision on their farms, as shown in Table 20.

With regard to the type of irrigation water used in the farm; pure TWW or mixed with fresh water, the answers were in the favor of using "pure TWW". In addition, the sample responded with "No" when asked about wearing flue masks while dealing with TWW for safety. Finally, the farmers most often didn't report any diseases on their plants. It is worth mentioning that these behaviors are not necessarily good. This might refer to the official supervisors not paying attention to the mentioned practices since they might not think they are important, or just ignoring them for a good or no so good reason. This eventually suggests that the farmers' awareness of supervision by official parties could also mean the absence of effective supervision, unless the supervisors are strict with implementing the set of regulations. However, supervision no doubt affects the attitudes of the farmers in a way or another, and it is highly correlated with the behaviors and conduct of the supervised farmers.

Table 20. Variation in farmers' response based on awareness of official supervision

Question	Answer	Percentage of respondents (%)	
		Supervised	Not supervised
Type of irrigation Water? P-value=0.013 chi-square=6.200, df=1	Mixed	2.7 (2.3)	28.3 (4.5)
	TWW	**97.3 (81.8)**	**71.7 (11.4)**
Wearing flue masks? P-value=0.013 chi-square=6.200, df=1	Yes	2.7 (2.3)	28.3 (4.5)
	No	**97.3 (81.8)**	**71.7 (11.4)**
Any diseases found on plants? P-value=0.014 chi-square=6.035, df=1	Yes	8.1 (6.8)	42.8 (6.8)
	No	**91.9 (77.3)**	**57.2 (9.1)**

The relationship between the famers using the treated effluent and encouraging new people to start using it was the clearest with a **P-value = 0.000** and the most simple. Farmers who were still using treated effluent in irrigation encouraged others to enter the field of reuse, and farmers who have stopped reusing it in their farms did not, see Table 21.

Table 21. Variation in farmers' response based on encouraging other farmers to start using treated water or not

Question	Answer	Percentage of respondents (%)	
		Yes	No
Is treated water still used in the farm? P-value=0.000, chi-square=18.805, df=1	Yes	**89.2 (75)**	14.5 (2.3)
	No	10.8 (9.1)	**85.5 (13.6)**

The results of training programs were noticed on the farmers' comprehension but not truly on their practices, see Table 22.

Table 22. Variation in farmers' response based on whether the farmer has received any training related to dealing with TWW

Question	Answer	Percentage of respondents (%)	
		Yes	No
Is the farmer aware of the environmental risks associated with using treated effluents in irrigation? P-value=0.000 chi-square=15.548, df=2	Yes	**81.8 (40.9)**	23.8 (11.4)
	No	18.2 (9.1)	**76.2 (36.4)**
Is the farmer aware of the recommended safety measures for dealing with treated effluents? P-value=0.008 chi-square=6.947, df=1	Yes	**100 (50.0)**	**72.8 (36.4)**
	No	0	27.2 (13.6)
Do farmers wear plastic suits while dealing with treated water for safety? P-value=0.036 chi-square=4.400, df=1	Yes	18.2 (9.1)	0
	No	**81.8 (40.9)**	**100 (50.0)**

When asked about the environmental risks associated with the usage of treated effluents in irrigation and the safety measures recommended to be followed, 81.8% and 100% of the trained farmers knew about them, respectively. On the other hand, 76.2% of the untrained farmers didn't knew about the environmental risks, while 72.8% of them knew about the safety measures related to dealing with this kind of irrigation water. Nevertheless, 81.8% of the trained farmers wore plastic suits for safety, while all of the untrained farmers wore them before irrigating their crops. It should be known that the ratio of the trained to the untrained farmers is fifty-fifty, see Table 22.

Regarding the variation in farmers' response based on age categories which is represented in Table 23, and whether the farmers were aware of the environmental benefits associated with reuse or not; the result was 72.8% of them did not know any of these benefits with the highest percentage of them (37.5%) belonged to the age range of (41-50 yrs.). In the same context, only 19.9% of the same age category knew about these benefits. Remarkably, not even one farmer above 50 know any environmental benefits of reuse occupying the highest percentage of ignoring them, and only 28% of the young farmers (20-30) knew some of these benefits. On the other hand, 53.9% of the farmers aged 31 to 40 knew about these benefits achieving the highest rates of knowledge of the environmental benefits associated with reuse of TWW in agriculture.

Table 23. Variation in farmers' response based on age

Question	Answer	Percentage of respondents (%)			
		20-30	31-40	41-50	Above 50
Is the farmer aware of the environmental benefits associated with reuse? P-value=0.038, chi-square= 8.409, df=3	Yes	28.3 (4.5)	**53.9 (15.9)**	19.9 (6.8)	0
	No	**71.7 (11.4)**	46.1 (13.6)	**80.1 (27.3)**	**100 (20.5)**
Type of irrigation system used in the farm P-value=0.036, chi-square= 13.467, df=6	Sprinkler irrigation	14.5 (2.3)	0	0	11.3 (2.3)
	SDI	0	23.1 (6.8)	26.7 (9.1)	**66.7 (13.6)**
	SSDI	**85.5 (13.6)**	**76.9 (22.7)**	**73.3 (25.0)**	22.1 (4.5)
	Surface irrigation	0	0	0	0
The period separating harvest from last irrigation P-value=0.041, chi-square= 17.554, df=9	Less than a week	42.9 (8.1)	**58.3 (18.9)**	**75.0 (24.3)**	0
	1-2 weeks	**57.1 (10.8)**	25 (8.1)	8.3 (2.7)	**50.0 (8.1)**
	2-3 weeks	0	8.3 (2.7)	8.3 (2.7)	0
	3 weeks or more	0	8.3 (2.7)	8.3 (2.7)	**50.0 (8.1)**

Regarding the type of irrigation system used in the farm, the result was 65.9% of the whole sample of farmers who preferred SSDI over the other systems of irrigation. 38.0% of those farmers (25.0% of the whole sample of farmers) belonged to the age category of (41-50 yrs.). The highest tendency towards preferring this method of irrigation was shown amongst the young farmers (20-30) with a percentage of 85.5%, while the percentage decreased gradually with aging. Only farmers above 50 adopted SDI system with a large percentage that reached

66.7%. It is worth mentioning that type of irrigation system was more related to the type of plant with a **P-value = 0.000** rather than age category with a **P-value = 0.036.**

37 farmers out of 44 answered the question about the period separating between irrigation suspending and harvesting. More than half the farmers answered “less than a week”. The third age category of (41-50) showed the highest consistency level with the a percentage of 75.0% answering “less than a week”, and once again the answers of the farmers above 50 were distinguished from the other age categories going fifty-fifty between “1-2 weeks” and “more than three weeks”, see Table 23.

4.7 Farmers’ Notes, Complaints and Additional Commentary

Farmers’ attitudes towards the reuse experiment they went through varied between positive and negative. One of them is convinced that the application of reuse in Palestinian territories is a bad idea and not going to work due to the lack of supervision and low government attention. Some of them blame the farmers themselves for not following the appropriate procedures while not pursuing to educate themselves any further as well as neglecting the safety measures. They also blame farmers for not paying the pill of water, which affects the permanence of the reuse project in spite of gaining satisfying profits.

Furthermore, farmers committed to pay for the price of TWW were deprived of having enough quantities on account of pumping huge quantities for those who do not pay. As explained previously in this research, mainly people cultivating alfalfa crops were the ones gaining the most satisfying profits. They were also the same people who were benefiting from the greatest share of discharged TWW and not committed to payment.

Eventually, the electricity company demanded the farmers for more than 100,000 ILS and began to cut off the electricity from time to time on the farmers as mentioned in ***section 4.4***. When the problem with the electricity company reached its prime, the fodders cultivating farmers stopped using the water and have not paid the previous bills yet. However, the few farmers who were still using the reclaimed water were the ones planting fruitful trees. Many farmers stopped irrigating their trees with TWW when they became fruitful. One of the farmers used the TWW until the fifth year. When the problem of disconnecting occurred, TWW became an unreliable source, so he stopped using it. It’s worth mentioning that in 2022, a solar project was approved with an external fund to reduce the electricity pill and TWW’s price so that it could attract the farmers to the reuse business once again in the future. Besides, a new fund is studied to establish a new irrigation project (N. Abu Ghazaleh, Personal communication, March 13, 2022).

A wild range of farmers looked at the TWW's price as expensive and should have been decreased, especially when compared with its quality. Same people would agree to some extent that water quality was better at the beginning then sharply deteriorated in few years. They would refer that to the lack of supervision in the treatment plant. The bad quality of the delivered TWW led to the spread of insects and smells, the growth of certain types of harming weed that destroyed their lands, and pipes blocking due to the high rates of TDS. Future studies on TWW's characteristics in comparison to the Palestinian standards and quality of treatment follow up should be paid more attention. In order to facilitate the job of the supervisors of Jenin's WWTP, a laboratory should be established in the plant as fast as possible so that they could perform the required regular tests, and even train them on how to recognize the defaults as soon as they happen and best fit solutions to them. N. Abu Ghazaleh (Personal communication, March 13, 2022) stated that a laboratory is expected to be established in the WWTP in 2022 or 2023 with a French fund.

4.8 The Characteristics of the outflow of Jenin's WWTP

As previously indicated in ***section 3.2***, the results of four tests of the TWW of Jenin's WWTP, in the period between 2014 and 2020, were provided by N. Atari (Personal communication, August 12, 2022) and attached in Annex 4. The tests were performed by three parties;

- NARC Lab. / National Agricultural Research Center, Jenin, Palestine
- Beta Lab. / National Agricultural Research Center, Nablus, Palestine
- NU Lab. / Water & Environmental Studies Institute (WESI), An-Najah National University, Nablus, Palestine / samples tested on ANERA's expense.

The four tests were performed in years 2014/ 2015/ 2016/ and 2020 as follows:

- Test 1 / March, 2014 by NU Lab.
- Test 2 / May, 2015 by NU Lab.
- Test 3 / 2016 by Beta Lab.
- Test 4 / September, 2020 NARC Lab.

The following parameters of the TWW, as mg/l is the used unit for DO, BOD_5, COD, and TSS, were discussed and analyzed in light of the Palestinian technical regulations for the reuse of treated wastewater in agricultural irrigation (PSI, TR-34, 2012, see Annex 3):

- pH (6-9 for qualities A, B, C, D).
- BOD_5 (20 for qualities A & B, 40 for quality C, 60 for quality D).
- COD (50 for qualities A & B, 100 for quality C, 150 for quality D).
- TSS (30 for qualities A & B, 50 for quality C, 90 for quality D).
- Fecal coliforms in colony/100 ml which is used interchangeably with MPN/100 ml (200 for quality A, 1000 for qualities B & C & D).
- Nematodes in eggs/l (≤ 1 for qualities A, B, C, D).

The results of pH obtained in Tests 2, 3 and 4 were 7.13, 6.90 and 8.11, respectively, which lie within the approved range by the Palestinian standards from 6 to 9.

The recorded results for BOD_5 were 16 and 15 for Test 1 and Test 3, respectively, achieving quality A based on the Palestinian standards. On the other hand, the recorded results for COD were 33, 55 and 128 for Tests 3, 4 and 1, falling within the quality categories of A, C and D, respectively, according to the Palestinian standards.

The Total suspended solids (TSS) reached 26 mg/l according to the test that was performed in 2014 (Test 1) below 30 mg/l which is the upper limit for quality A treated effluent.

Test 1 indicated a high content of fecal coliform with a result of 1500 CFU/100 ml exceeding the limits of all quality categories from A to D with a higher limit of 1000 CFU/ 100 ml. Test 1 also recorded a high contamination of nematodes (200 eggs/l). However, Test 2 and Test 4 recorded results slightly above the limit of 200 CFU/100 ml for category A. The result of fecal coliform in Test 2 was 230 and the result of total coliform in Test 4 was 290, notice that Test 4 gave the Total number of colonies (2900) for a one liter sample which is divided by 10 (2900/10 = 290) to be transformed into CFU/100 ml.

In short, the results of pH, BOD_5 and COD, in general, were indicating a good quality of treatment, while the lack of additional TSS results could not allow for a good comprehension on the issue of pipes blocking reported by the majority of the farmers. On the other hand, the results of fecal coliform and nematodes necessitate a more restricted supervision on the disinfection process and testing the quality of the TWW more often in order to ensure the safe use of the TWW by the farmers.

Chapter Five

Conclusions and Recommendations

5.1 Conclusions

This study was performed to investigate the characteristics of the set of the farmers who used the TWW in Jenin City; their level of knowledge, awareness and practices, as well as to investigate the obstacles and driving factors that affected them the most and led them away or in the direction of the agricultural reuse of TWW, and the observed effects of using RW in irrigation on different aspects as reported by the interviewed sample. Besides, it came as a documentary act to conclude the current status of reuse in Jenin city and to measure the level of supervision that is imposed on the farmers. The city is located in the fertile plains of Marj Ibn Amer which is considered the food basket of the historical Palestine. This is where the agricultural value of the city comes from.

The high agricultural share of the Palestinian national income is impeded by the water scarcity. Water scarcity contributes in the shortage of the agricultural share of fresh water and the high price of the purchased water. The approach of reusing treated wastewater is one of the most effective and less considered answers to the dilemma of water scarcity in the Palestinian territories. In the last decade, the orientation towards the construction and improvement of WWTPs, followed by the funding and establishing of irrigation projects using treated effluents has been the case in several Palestinian cities and villages. Some of these projects targeted Jenin, Nablus, Jericho, and some small villages like ‘Anza. Success of these projects was either handicapped by the small reused quantities of treated water due to the small discharge of the targeted treatment plant or the lack of the agricultural land near the WWTPs.

However, in the case of Jenin City, the abundance in both agricultural land and treated wastewater promised a bright future of reuse in the city. After the rehabilitation of the treatment plant in 2010 by the KFW, ANERA funded the reuse irrigation project in 2015 which seemed to be fruitful in the first stages and started to attract the eyes of researches and developers towards it. Later on, the negligence of the reuse project on the side of the farmers, funders, and agricultural department in Jenin City as well as the bad maintenance of the treatment plant by the municipality has put these tremendous efforts to waste year by year. Eventually, most of the farmers had to withdraw out of the reuse business.

The sample size equaled the sample space of 44 male farmers who used the treated effluent of Jenin's WWTP. Their ages ranged from 21 to 65 years old. 28 farmers of them were middle aged whose ages ranged between 31 and 50 years old. 56.8% of the farmers practiced agriculture as a major career, while 43.2% of them practiced it as a secondary source of income. These facts could mean that agriculture in general and agriculture on RW in particular are not reliable sources of income. It is the government's responsibility to support the Palestinian agricultural sector and the Palestinian farmers to stop the deterioration in this vital sector and one of the main income sources for the proud Palestinian people.

The aggregate cultivated area irrigated with treated effluent reached 585.5 dunum, most of which were self-owned farms with an average size of 1.33 ha each. The government is expected to play a crucial role in exploiting the abandoned areas by facilitating and encouraging land's renting. Almost 60% of the farms were between 10 and 30 dunum in area and were categorized within the medium sized farms. Besides, Three quarters of the farms offered job for less than 5 farmers while the overall number of labors reached 132 with an average of 3 labors per farm. 41 farmers relied only on treated wastewater for irrigating their crops. 40.9% of the farms were fenced while 59.1% were not, and only 11.4% of the farms were close to housing areas while the remaining 88.6% were far enough from the nearest housing areas. 86.4% of the farmers finished their secondary education, and 13.6% of them quit during their mid school. 34.1% of the farmers got a college degree.

29 farmers out of 44 (65.9%) grew alfalfa crops while 13 out of 44 (29.5%) grew fruitful trees and only two of them grew both. The percentage of farmers who didn't use any type of fertilizers reached 59.1%, and 36.4% of them relied on some manufactured nutrients without mixing it with natural fertilizers. However, 16 farmers kept using the same quantity of fertilizers they used to use before turning to the usage of treated effluents in their farm, while the rest of them either reduced or completely stopped fertilizing their crops. Remarkably, none of them has increased the fertilizers quantities in his farm. Regarding irrigation systems, the farmers relied on SSDI, SDI, and surface irrigation. The most used irrigation system with a percentage of 65.9% was SSDI and used more in the irrigation of alfalfa crops, followed by SDI with a percentage of 29.5% which was utilized more in growing fruitful trees.

The farmers didn't have the knowledge of the appropriate quantities of TWW required for their crops. They randomly irrigated their crops with different water quantities which wasn't based a scientific approach. This practice raised the monthly cost on these farmers due to the additional water quantities, which could have been saved, and drove some of them to stop buying the water. Moreover, such a practice could increase the soil salinity and affect its fertility negatively. Although the farmers had acknowledged the presence of N, P, K and other minerals within the TWW which led them to reduce their usage of manufactured fertilizers, that reduction wasn't based on a scientific approach as well. If the concentrations of these nutrients are known through performing regular tests of the water, then the amounts of these nutrients can be easily known for each cubic meter of water. Thus, the decision of fertilizers' reduction could be justified and precisely determined to help the plant having its need of nutrients and at the same time protect the soil from salinization due to excess irrigation.

The majority of the farmers confirmed their direct connection with the treated wastewater. From most to less considered, gumboots, gloves, plastic suits, and masks were the main safety measures adopted by the farmers. Six farmers reported signs of disease on plants while no effects on animals or men were reported. Five farmers kept irrigating their fruitful trees until the harvest day with the claim that fruits should remain fresh that way. The farmers who adopted the separation strategy were categorized into four categories based on the period; from one to seven days (51.4%), less than two weeks (29.7%), less than three weeks (5.4%), and more than three weeks (13.5%). 3 farmers out of the 13 growing trees didn't hesitate to pick up the falling fruits off the ground and sell them. On the other hand, all the fodder growing farmers abstained from selling their crop before drying it. The farmers used the treated effluent from 5 to 9 months yearly. Only one user of the treated effluent labeled his product as irrigated with treated water, leaving 97.7% of them selling their crops without any labels or any other notation referring to their crops being irrigated with treated water.

All of the fodder-growing farmers claimed that their customers had the previous knowledge that they are buying treated water irrigated fodder. Having in their minds that the Israeli products irrigated with TWW are sold in the Palestinian markets unlabeled; the fruit growing farmers copied the same practice, otherwise, their products could be rejected by the consumers according to the farmers.

The study concluded that the farmers tended to be more motivated or at least less affected than hindered in the sight of the 18 factors which have been investigated in the research. The establishing and funding of the reuse irrigation project was the primary force that drove the farmers towards reuse and spread the acceptance of the idea amongst Jenin's farmers. The 44 interviewed farmers considered the establishing and funding of an irrigation project to be the cornerstone for any reuse project. The second most important driving factor was the price of

TWW compared to the fresh water prices. 81.8% and 77.3% of the farmers, respectively, voted for “type of the crop they used to grow in their farms” and “pilot project success” in the third and fourth places as the most essential motivating factors. Availability of fresh water, site of the farm away from the nearest housing areas, and the incentives presented by the government came later in the list of the motivating factors. 31.8 % of the farmers didn’t consider the scarcity of fresh water to be severed and claimed that they can still buy it as a resort whenever the quality of the treated water deteriorates significantly.

The main obstacles and worries the farmers faced before entering the field of reuse were; disgust (68.2%), fear of the bad supervision on the treatment process and the quality of the produced water by the labors of the treatment plant (68.2%), fear on their health dealing with a water source that is contaminated with pathogens (63.6%), the worries of the side effects on the soil of their farms (63.6%). One of the farmers stopped using the water after observing some of the side effects on the soil of his land and, according to him; it took him two years of soil rehabilitation to recover from those side effects. Religious worries and the lack of experience came fifth and sixth in the list of obstacles with percentages of (56.8%) and (54.5%), respectively.

The factors with the least impact on the farmers’ decision regarding their entrance into the reuse business were; the effects on environment, the effects on crop quality, the awareness campaigns that would target the consumers of their products, and marketing. According to three farmers only, all their worries and concerns were vanished after their experience in dealing with treated wastewater. However, the farmers’ mentality was shifted positively regarding the religious and psychological (disgust) worries and negatively in the fields of distrusted water quality claimed to be due to the deficient supervision in the WWTP, the negligence on the part of the government towards the farmers, and the price of treated wastewater. The concerns for marketing and environment were still seen unimportant by the farmers representing the lowest affected aspects amongst all.

The farmers were asked to report their observations of the effects of using the treated wastewater on the following aspects. The positive impacts were noticed highly on the produced quantities (77.3%), crop quality (50.0%), and the marketing of the agricultural products (47.7%). On the other hand, the highest negative impacts were seen on irrigation systems due to pipes’ blocking (77.3%), as well as the emission of unpleasant odors (54.5%). The highest contributors to the *“no difference” index* were the impacts on human health (100%), soil quality (56.8%), and the spread of insects (54.5%).

5.2 Recommendations

This section highlights the recommendations suggested by the study. Official parties, concerned developers, researchers, and farmers' associations are addressed by these recommendations in light of improving the reuse industry in Jenin City and the world. These recommendations are:

1. Since agriculture in Palestine is taken as a part time job by half the Palestinian farmers, a result found in this thesis and Mizyed's (2013) study, the government should support the agricultural sector in Palestine, in general, and the reuse of TWW as a strategic tool, in particular, so that agricultural can be considered a full time job and allow for a prosperous future of reusing treated effluents in agriculture.
2. Most of the farms in this study were self-owned, confirming Mizyed's (2013) findings. The Palestinian authorities should encourage exploiting the abandoned lands through setting proper regulations and plans to increase and facilitate renting.
3. The Palestinian regulations, rules and strategies should be reconsidered and redefined in fit with encouraging and controlling the sustainable agricultural reuse industry amongst the Palestinian farmers, in a way that increases the involvement of the government as well as the farmers' involvement in setting future plans in this field. Besides, the farmers should be educated on the Palestinian regulations of reuse.
4. More attention should be paid to the supervision on the farmers' practices.
5. Future studies should target the side effects of reuse on crop quality and soil. More attention should be paid to preserving the soil fertility and supervising should be through specified and clear steps based on these studies. Soil rehabilitation and soil recovery should be defined and applied in steps wherever and whenever the soil is damaged.
6. Sustainability courses should be included in the farmers' training programs. At some point the reuse project in Jenin was considered successful, until the farmers started to step out of business one after another due to the lack of knowledge in sustainable management.
7. It is recommended to organize irrigation quantities based on water requirement for each crop and supervise the quantities utilized by the farmers based on crop type and area of the farm. Excess water quantities would lead to soil salinization and increase the additional cost burden on the farmers decreasing their returns which might affect the sustainability of their projects.
8. It is recommended to perform more studies regarding water quantities and soil salinity.

9. Farmers should not decide the quantities of fertilizers randomly. Additional fertilizers should consider the nutrients' quantities already contained in TWW. Additional fertilizers could then be estimated via determining the concentrations of nutrients in TWW by periodical tests, irrigation quantities, and crop's need of nutritious matter.
10. The crops produced from TWW reuse should be labeled and marketed to the customers through consecutive awareness campaigns.
11. Regular tests of the effluent should be carried more often to confirm the water quality and the results of these tests should be exhibited to the farmers to increase their trust in the agricultural department and the operators of WWTP.
12. It is recommended to equip each WWTP with an internal laboratory and experts to perform the regular tests.
13. Disinfection has to be included and supervised with extreme care to protect the farmers who indeed confirmed the frequent, direct contact with the TWW, especially with them paying less attention to the safety measures.
14. Relying on renewable and sustainable sources of energy besides electricity. A small solar system project is approved to be added to the WWTP to reduce the bill of electricity used for pumping the effluent to the farms as well as the TWW's price. A larger project should target the huge operational costs of the treatment Plant.

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Annex 1: Questionnaire in English

BIRZEIT UNIVERSITY
Birzeit, Palestine

Questionnaire: survey on farmers' knowledge, practices and driving forces for the reuse of municipal treated effluents wastewater in irrigated agriculture in Palestine

Dear farmer,

After greetings,

Our student Ahmad Alsadi is performing a study as a complementary research for his master degree in water and environmental engineering in Birzeit University, holding the title of:

Use of treated municipal wastewater in irrigated agriculture in Palestine: driving forces and practices

The interview is supposed to take around 20 minutes only. The provided data will only be used for academic purposes, and no personal information shall be spread or misused in any condition. We are thankful for your cooperation.

BIRZEIT UNIVERSITY
Birzeit, Palestine

Questionnaire: survey on farmers' knowledge, practices and driving forces for the reuse of municipal treated effluents wastewater in irrigated agriculture in Palestine

Identifying information:

			☐☐	Questionnaire number	ID1
				Name of interviewee	ID2
1. male 2. Female ☐	Gender	ID4	☐☐	Age	ID3
				City/ village	ID5
				Mobile number	ID6
			20...../......./........	Date	ID7

General information regarding farmer and the irrigated farm:

1. major 2. secondary	☐	Do you practice agriculture as a …… career?	G1
Person	☐☐	How many people work in your farm?	G2
Acres	☐☐☐	What is the farm's area?	G3
1. fresh water 2. treated water 3. both Quantities for each source Fresh water ……………… Treated water…………….	☐ ☐ ☐	What kind of water do you use in your farm? (Quantities in m^3/dunum/month)	G4
1. Yes 2. No	☐	Is the farm fenced to prevent the entrance of man and animal?	G5
1. Yes 2. No	☐	Is the farm close to housing areas?	G6

Water Prices:

What is the price of one cubic meter of treated water ………. ILS			PC1
What is the price of one cubic meter of fresh water ………. ILS			PC2
1. Yes 2. No (in case of choosing no, please explain) ………………………..	☐	Are you satisfied with the current price of treated water?	PC3

Questions measuring the level of knowledge:

1. primary 2. middle 3. secondary 4. collage	☐	What is your highest degree?	K1
1. Yes 2. No	☐	Are you aware of the environmental benefits associated with using treated effluents in irrigation?	K2
1. Yes 2. No	☐	Are you aware of the environmental risks associated with using treated effluents in irrigation?	K3
1. Yes 2. No	☐	Are you aware of the health risks associated with misusing treated effluents in irrigation?	K4
1. Yes 2. No	☐	Are you aware of the recommended safety measures for dealing with treated effluents?	K5
1. Yes 2. No	☐	Are you aware of nutritious content of/within the treated effluents (Nitrogen/ phosphorous/ …) and its effect on the need of using fertilizers?	K6
1. Yes 2. No	☐	Are you aware of the Palestinian specifications and TORs associated	K7

		with the wastewater reuse in irrigation?	
1. Yes 2. No	☐	Have you ever been to any training courses related to wastewater reuse?	K8
1. Yes 2. No	☐	Are you willing to increase your knowledge in the field of reuse?	K9

Practices:

1. fruitful trees 2. alfalfa crops 3. both	☐	What do you plant in your farm?	P1
1. Yes 2. No	☐	Do you mix fresh water with treated water?	P2
1. natural 2. manufactured 3. both 4. I don't use any	☐	What type of fertilizers is used in your farm?	P3
1. quantity reduced 2. quantity increased 3. nothing changed 4. I don't use fertilizers anymore	☐	Have you changed the fertilizers' quantities after using treated effluents?	P4
1. sprinkler irrigation 2. SDI 3. SSDI 4. surface irrigation	☐	What is the used irrigation system in your farm?	P5
1. Yes 2. No	☐	Is there any contact between labors and the treated effluent?	P6
1. gloves 2. flu masks (or masks in general) 3. gumboots 4. plastic suits	☐ ☐ ☐ ☐	Do farmers wear any safety clothing when they want to irrigate or deal with treated water?	P7

		Choose one of the following potential answers : 1. Yes 2. No	
1. plant 2. animal 3. man	☐ ☐ ☐	Have you noticed any disease on plant animal or man? *Choose one of the following potential answers :* 1. Yes 2. No	P8
1. Yes 2. No	☐	Do you consider a separating period between last irrigation and harvest day?	P9
1. less than a week 2. less than two weeks 3. less than three weeks 4. more than three weeks	☐	Determine the period that separates the harvest day from last irrigation?	P10
1. Yes 2. No Mention some of these procedures ………………………………………	☐	Do farmers take any safety measures on harvest day?	P11
1. Yes 2. No (answer only in the case of fruitful trees)	☐	Do you pick up falling fruits off the ground?	P12
1. the crop is sold directly after harvesting 2. it's sold after it's dried (answer only in the case of alfalfa)	☐	After harvesting the crop, is it sold directly or after it is dried?	P13
How many months in the year do you use treated effluent? ………… month			P14
1. I rely on rain 2. I don't grow plants on those months 3. I grow other plants irrigated with fresh water Other reasons ……………………….	☐	Why don't you irrigate with the treated effluent on the other months?	P15

1. Yes 2. No	☐	Do you use labels on your products as an indication that they have been irrigated using treated effluent?	P16

Supervision:

1. Yes 2. No From what party are they? ……………..	☐	Do official supervisors visit your farm?	S1
1. Yes 2. No Such as …………………………………	☐	Have you heard of sanctions/ penalties being applied for violating the Palestinian regulatory laws?	S2
1. Yes 2. No	☐	Is there supervision on water quality?	S3
1. once per month 2. once in three months 3. once in six months 4. once per year 5. less than once a year	☐	If the answer is yes, determine how frequent water samples are taken.	S4
1. official parties 2. supervisors from wastewater plant 3. agricultural institutions and associations 4. I take samples by myself	☐	Who takes water samples?	S5
1. Yes 2. No	☐	Do you have reports for water quality?	S6
1. Yes 2. No	☐	Is the quality of plant/crop/fruit supervised?	S7
1. once per month 2. once in three months 3. once in six months 4. once per year 5. less than once a year	☐	If the answer is yes, determine how frequent plant samples are taken.	S8
1. official parties 2. agricultural institutions and associations 3. I take samples by myself	☐	Who takes plant samples?	S9
1. Yes 2. No	☐	Is the quality of soil supervised?	S10
1. once per month 2. once in three months 3. once in six months		If the answer is yes, determine how frequent soil samples are taken.	S11

4. once per year 5. less than once a year			
1. official parties 2. agricultural institutions and associations 3. I take samples by myself	☐	Who takes soil samples?	S12

Motives and obstacles:

1. low quantities of fresh water for irrigation 2. treated water price 3. care for the environment (groundwater, wild life, …) 4. care for health 5. marketing 6. effect on crop quality 7. effect on soil 8. low experience in the field 9. success of a pilot project or a farmer you know of 10. incentives by the government 11. government having role towards farmers by guiding, supervising and training them 12. Type of crop growing in the farm (please clarify ………………………) 13. trust in the supervision on treated water quality by wastewater plant	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	Which of the following was considered as a motive, an obstacle or neither at the time you started using the treated effluent? *Choose one of the following potential answers :* 1. motive 2. obstacle 3. neither	V1

14. farm's site (close to or far from housing areas or the treatment plant) 15. awareness camps 16. starting an irrigation project in the area 17. religious worries 18. psychological worries (disgust)	☐ ☐ ☐ ☐		
1. Yes 2. No	☐	Do you still have fears, hardship or worries?	V2
1. treated water price 2. harms on the environment (soil, groundwater, wild life, …) 3. carelessness of government towards farmers by not guiding, supervising or training them 4. no trust in the supervision on treated water quality by wastewater plants 5. marketing 6. religious worries 7. psychological worries (disgust)	☐ ☐ ☐ ☐ ☐ ☐ ☐	What are those fears, hardship or worries? *Choose one of the following potential answers :* 1. still makes an obstacle *2.* not an obstacle anymore	V3
1. crop quantity 2. crop quality 3. insects increase 4. unpleasant odors 5. soil quality 6. health 7. marketing	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	What are the anticipated effects of using the treated effluent? *Choose one of the following potential answers :* 1. positive 2. negative 3. no difference	V4

8. irrigation system			
1. Yes 2. No	☐	Do you encourage other farmers to start using the treated effluent?	V5
1. Yes 2. No	☐	Do you still use the treated effluent?	V6

Do you have any notes or side comments that you would like to add?

....
....
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....

We appreciate your cooperation

Annex 2: Questionnaire in Arabic

BIRZEIT UNIVERSITY
Birzeit, Palestine

استمارة مسح القوى الدافعة والممارسات لاستخدام المياه المعالجة للري في الاراضي الفلسطينية

أخي المزارع،،،

تحية وبعد

يقوم الطالب أحمد السعدي بإجراء دراسة لمتطلب رسالة الماجستير في تخصص هندسة المياه والبيئة في جامعة بيرزيت، وهي بعنوان:

استخدام المياه العادمة البلدية المعالجة في الزراعة المروية في فلسطين: القوى الدافعة والممارسات والآثار المترتبة

ستستغرق المقابلة حوالي 20 دقيقة فقط. ستستخدم المعلومات المزودة لاغراض البحث العلمي فقط، ونتعهد بعدم البوح بأي معلومات شخصية أيا كانت، وشكرا لحسن تعاونكم.

BIRZEIT UNIVERSITY
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استمارة مسح القوى الدافعة والممارسات لاستخدام المياه المعالجة للري في الاراضي الفلسطينية

البيانات التعريفية:

ID1	رقم الاستمارة	☐☐				
ID2	اسم المبحوث					
ID3	عمر المبحوث بالسنوات	☐☐	ID4	الجنس	☐	1. ذكر 2. أنثى
ID5	اسم المدينة او القرية					
ID6	تلفون					
ID7	تاريخ استيفاء الاستمارة	20...../......./........				

معلومات عامة حول المزارع والمزرعة المروية:

G1	هل تمارس عملك في الزراعة كمهنة ......؟	☐	1. اساسية 2. ثانوية
G2	كم عدد العاملين في مزرعتك؟	☐☐	شخص
G3	ما هي مساحة المزرعة؟	☐☐☐	دونم
G4	ما طبيعة المياه التي تسقى بها؟ (مع الكميات الشـــهرية بالشـــيقل او المتر المكعب ان أمكن) *سجل داخل المربع احد الاجابات التالية:* 1. نعم 2. لا	☐ ☐ ☐	1. مياه عذبة 2. مياه معالجة 3. كلاهما حدد الكميات لكل مصدر؟ ....
G5	هل المزرعة محاطة بســـياج يمنع دخول الانســـان والحيوان؟	☐	1. نعم 2. لا

G6	هل المزرعة قريبة من منطقة سكنية؟	☐	1. نعم 2. لا

اسعار وكميات المياه:

PC1	ما سعر الكوب من المياه المعالجة بالشيقل		
PC2	ما سعر الكوب من المياه العذبة بالشيقل		
PC3	هل انت راضي عن سعر المياه المعالجة؟	☐	1. نعم 2. لا (وضح السبب وحدد السعر المناسب لك في حال الاجابة ب لا: ....)

معلومات تتعلق بقياس مستوى المعرفة لدى المزارع الفلسطيني:

K1	ما اعلى درجة علمية حصلت عليها؟	☐	1. اساسية 2. اعدادية 3. ثانوية 4. جامعية
K2	هل انت مدرك للميزات البيئية المتعلقة باستخدام المياه المعالجة في الري؟	☐	1. نعم 2. لا
K3	هل انت على معرفة بالمخاطر البيئية المترتبة على اساءة استخدام المياه المعالجة في الري؟	☐	1. نعم 2. لا
K4	هل انت على معرفة بالمخاطر الصحية المترتبة على اساءة استخدام المياه المعالجة في الري؟	☐	1. نعم 2. لا
K5	هل انت على معرفة باجراءات السلامة اللازم العمل بها عند التعامل مع المياه المعالجة؟	☐	1. نعم 2. لا
K6	هل تعلم بوجود محتوى غذائي بالمياه المعالجة (نيتروجين/ فوسفور/...) قد يغني عن التسميد او يقلل من كمية السماد اللازم؟	☐	1. نعم 2. لا

K7	هل انت على معرفة بالمواصفة الفلسطينية الخاصة باستخدم المياه المعالجة لاغراض الري؟	☐	1. نعم 2. لا
K8	هل خضعت لأي دورات تدريبية في ما يخص الري بالمياه المعالجة؟	☐	1. نعم 2. لا
K9	هل ترغب بزيادة معرفتك في هذا المجال؟	☐	1. نعم 2. لا

<u>الممارسات:</u>

P1	ما هي المزروعات المتوفرة في مزرعتك المروية بالمياه المعالجة؟ *سجل داخل المربع احد الاجابات التالية:* 1. متوفرة 2. غير متوفرة	☐ ☐ ☐ ☐ ☐	1. أشجار مثمره 2. خضروات تؤكل نيئة 3. خضراوات تؤكل مطبوخة 4. قمح 5. أعلاف
P2	هل يتم خلط المياه المعالجة بمياه عذبة عند الري؟	☐	1. نعم 2. لا 3. احيانا
P3	ما نوع السماد المستخدم في المزرعة؟	☐	1. طبيعي 2. صناعي 3. كلاهما 4. لا يتم استخدام السماد (انتقل الى SP7 ان كنت لا تستخدم السماد)
P4	هل قمت بتغير كمية السماد المستخدمة بعد استبدالك المياه العذبة بالمياه المعالجة؟	☐	1. قللت الكمية 2. زدت الكمية 3. لم تتغير الكمية 4. لم اعد استخدم السماد
P5	ما هي طريقة الري المستعملة؟	☐	1. الرشاش 2. التنقيط 3. التنقيط تحت الارض 4. الري الحر

P6	هل يحدث اي تلامس بين المزارعين والمياه المعالجة؟	☐	1. نعم 2. لا
P7	هل يرتدي المزارعون اي ملابس وقائية عند عملية الري كإجراء سلامة؟ الاجابة داخل المربع احد الخيارات ادناه: 1. نعم 2. لا	☐ ☐ ☐	1. قفازات 2. كمامات 3. جزمة
P8	هل اصاب مرض النبات او الانسان او الحيوان جراء استخدام المياه المعالجة؟ الاجابة داخل المربع احد الخيارات ادناه: 1. نعم 2. لا	☐ ☐ ☐	1. النبات 2. الحيوان 3. الانسان
P9	هل يوجد فاصل زمني بين اخر عملية ري وبين الحصاد او جني الثمار؟	☐	1. نعم 2. لا
P10	ما المدة الفاصلة بين اخر ري بالمياه المعالجة و الحصاد او جني الثمار؟	☐	1.اقل من اسبوع 2. اقل من اسبوعان 3. اقل من ثلاثة اسابيع 4. اكثر من ثلاثة اسابيع
P11	هل يتم اتخاذ اي اجراءات سلامة عند حصد (جني ثمار) المحاصيل المروية بالمياه المعالجة؟	☐	1. نعم 2. لا عدد بعضها ان وجد .....
P12	هل يتم التقاط الثمار الساقطة على الارض وبيعها؟	☐	1. نعم 2. لا (الاجابة فقط في حال زراعة اشجار مثمرة)
P13	بعد عملية الحصاد، هل يتم بيع المحصول مباشرة ام يتم تجفيفه في حالة الاعلاف؟	☐	1. نعم 2. لا (الاجابة فقط في حال زراعة الاعلاف)
P14	في أي من اشهر السنة يتم الري باستخدام المياه المعالجة؟	☐ ☐ ☐	كانون ثاني – 1 شباط –2

	الاجابة داخل المربع احد الخيارات ادناه: 1. يتم الري 2. لا يتم الري		3- آذار 4- نيسان 5- أيار 6- حزيران 7- تموز 8- آب 9- ايلول 10- تشرين اول 11- تشرين ثاني 12- كانون اول
P15	لماذا لا يتم استخدام المياه المعالجة في باقي الاشهر؟		1. الاعتماد على مياه المطر 2. لا أزرع في تلك الفترة 3. أزرع منتجات أخرى تسقى بمياه عذبة 4. غيرها ....
P16	هل يتم وضع ملصقات تسويقية (labels) تبين أن المنتج مروي بالمياه المعالجة قبل التسويق؟		1. نعم 2. لا

الرقابة:

S1	هل يزور المزرعة مفتشون من جهات حكومية لمراقبة عملية الري؟		1. نعم 2. لا من أي جهة هم؟ ....
S2	في حال المخالفة هل يتم اخذ اجراءات قانونية (عقوبات)؟		1. نعم 2. لا مثل؟ ....

S3	هل يتم الرقابة على جودة المياه؟	☐	1. نعم 2. لا 3. لا أعلم
S4	في حال أجبت بنعم، حدد المدة	☐	1. مرة كل شهر 2. مرة كل 3 شهور 3. مرة كل 6 شهور 4. مرة في السنة 5. اكثر من ذلك 6. لا أعلم
S5	من يقوم بأخذ العينات؟	☐	1. جهات حكومية 2. مراقبون من محطة المعالجة 3. مؤسسات وجمعيات زراعية 4. اقوم باخذ العينات بنفسي
S6	هل لديك تقارير عن جودة المياه؟	☐	1. نعم 2. لا
S7	هل يتم اخذ عينات لفحص النبات المروي بالمياه المعالجة؟	☐	1. مرة كل شهر 2. مرة كل 3 شهور 3. مرة كل 6 شهور 4. مرة في السنة 5. اكثر من ذلك 6. لا يتم اخذ عينات
S8	من يقوم باخذ العينات؟	☐	1. جهات حكومية 2. مؤسسات وجمعيات زراعية 3. اقوم باخذ العينات بنفسي
S9	هل يتم أخذ عينات لفحص التربة بشكل دوري؟	☐	1. مرة كل شهر 2. مرة كل 3 شهور 3. مرة كل 6 شهور 4. مرة في السنة 5. اكثر من ذلك 6. لا يتم اخذ عينات (انتقل الى SP14 ان كنت لا تستخدم السماد)
S10	من يقوم باخذ العينات؟	☐	1. جهات حكومية 2. مؤسسات وجمعيات زراعية 3. اقوم باخذ العينات بنفسي

محفزات ومعيقات:

V1	أيا من الامور التالية كان محفزا او معيقا قبل البدء باستخدام المياه المعالجة؟	☐ ☐	1. عدم توفر مياه كافية للزراعة 2. سعر المياه المعالجة

	الاجابة داخل المربع احد الخيارات ادناه: 1. محفزا 2. معيقا 3. لا ينطبق	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	3. الاهتمام بالبيئة (مياه جوفية، حياة برية، ... الخ) 4. الاهتمام بالصحة العامة 5. التسويق 6. الاضرار بجودة المحاصيل 7. الاضرار بجودة التربة 8. قلة الخبرة في المجال 9. نجاح مشروع تجريبي او تجربة غيرك من المزارعين 10. تقديم حوافز من الحكومة 11. اهتمام الحكومة بتوجيه المزارعين ومراقبتهم 12. نوع المحاصيل التي كنت تزرعها (يرجى التوضيح ....) 13. الثقة بالرقابة على جودة المياه المعالجة الخارجة من محطات المعالجة 14. موقع المزرعة (قريب او بعيد عن المناطق السكنية او المحطة) 15. حملات توعية 16. انشاء مشروع ري 17. اسباب دينية (فيما يخص مفهوم النجاسة وما شابه ذلك) 18. مخاوف نفسية (عدم الرغبة بالتعامل مع المياه المعالجة لانها آتية في الاصل من مياه عادمة)
V2	هل لا يزال عندك تخوفات في الوقت الحالي؟	☐	1. نعم 2. لا

V3	ما هي هذه التخوفات/ المعيقات؟ *سجل داخل المربع احد الاجابات التالية:* 1. لا تزال تشكل عائقا 2. ليست عائقا	☐ ☐ ☐ ☐ ☐ ☐ ☐	1. سعر المياه المعالجة 2. الاضرار بالبيئة (تربة، مياه جوفية، حياة برية، ...) 3. عدم الاهتمام من قبل الحكومة بتوجيه المزارعين ومراقبتهم وتدريبهم 4. عدم الثقة بالرقابة على جودة المياه المعالجة الخارجة من محطات المعالجة 5. الزام الحكومة المزارعين بوضع علامات تشير بأن منتوجاتهم تم ريها بمياه معالجة 6. اسباب دينية (فيما يخص مفهوم النجاسة وما شابه ذلك) 7. مخاوف نفسية (عدم الرغبة بالتعامل مع المياه المعالجة لانها آتية في الاصل من مياه عادمة)
V4	ما هي الآثار التي لاحظتها بعد استخدامك للمياه المعالجة؟ *سجل داخل المربع احد الاجابات التالية:* 1. ايجابا 2. سلبا 3. لم يتغير	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	1. كمية المحصول 2. جودة المحصول 3. انتشار الحشرات 4. انبعاث الروائح 5. التربة 6. الصحة 7. التسويق 8. نظام الري غير ذلك ....

V5	هل تشجع المزارعين الاخرين بالبدء باستخدام المياه المعالجة؟	☐	1. نعم 2. لا

هل لديك اي ملاحظات او تعليقات تود اضافتها؟

………
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نشكركم على التعاون

Annex 3: Technical Regulations for the reuse of treated wastewater in agricultural irrigation (PSI, TR-34, 2012):-

Technical Regulations for the reuse of treated wastewater in agricultural irrigation (PSI, TR-34, 2012) (Nassar, 2019):-

Introduction

These technical directions aim at the followings:

1. To put basics to use the treated water in agricultural irrigation in a way that will not affect badly the health of the human, animal, and plants.
2. Ensure that the treated sewage water in irrigation will not cause damage to any of the environmental elements including water soil, and air.

Article (1) The scope

The provisions of these regulations are for the treated sewage water that comes out of the treatment stations for using in agricultural irrigation.

Article (2) Definitions

For implementing the regulations of these directions, the following words and expressions have the stated meanings unless the context indicates otherwise:

2-1 The competent authority: is the party or the parties that determined by the cabinet in order to implement the regulations of these directions according to article (23) of the law of Standard Institution and other related applicable regulations.

2-2 User: a person, a contractor, or governmental, private, or civil institution that use or get benefit from the treated sewage water for agricultural irrigation.

2-3 Wastewater: the contaminated water with physical, chemical, biological, or radiological materials that resulted from the use of the domestic, industrial, commercial, or agricultural uses and becomes dangerous when being reused or discharged contrary to the provisions of relevant laws and regulations.

2-4 The Maximum Limits: Is the maximum concentration of a pollutant allowed to exist in treated sewage water, according to the limit mentioned in these instructions.

2-5 Treated sewage water: Is sewage water that has been clarified from some or all its suspended, sediment and dissolved materials by natural or mechanical, chemical or biological methods, whether individually or collectively, which do not exceed the maximum levels listed in these instructions.

2-6 Wastewater treatment station: group of facilities and equipment prepared to treat the wastewater by natural, chemical, mechanical, or biological methods, in order to improve the characteristics of wastewater to be reused it or discharged without any health or environment damages.

Article (3) The waste water for agricultural irrigation classified according to its quality to classifications mentioned in the Table (1)

Article (4) The following conditions should be implemented to use the treated water for agricultural irrigation:

a) To be in accordance to these directions especially to the Table (1)

b) Approval of the concerned authority on this agricultural irrigation use in accordance with permits issued by it for this purpose, consistent with the requirements of these instructions.

Article (5)

1-5 To transport the treated wastewater for agricultural irrigation in closed appropriate pipes and colored in purple and applicable to the Palestinian specifications.

2-5 if the treated wastewater is transferred by using a vehicle tanks, these tanks should be colored in purple and write on it with a clear obvious font visual from both sides (treated water for agricultural irrigation).

Article (6) The relevant authority shall set instructions explaining protective measures to be taken within the farm when dealing with the treated wastewater for agricultural irrigation

Article (7) The relevant authority shall monitor the quality of treated wastewater for agricultural irrigation by applying the control system described in Palestinian Standard No. 742

Article (8) Its prevented to use the treated wastewater for agricultural irrigation in the followings:

a) Watering of livestock and poultry

b) Irrigation for all types of vegetables

c) Groundwater recharge by direct injection

d) Fish farming

Article (9) User should not use the treated wastewater for irrigation in uses other than those identified by relevant agricultural irrigation party.

Article (10) When there is a conflict with the official documents issued by other parties, these documents should be modified to become in line with these instructions.

Article (11) These instructions are applicable from the date of the approval, and advertising.

Article (12) In case of any dispute in the interpretation of any text of these instructions, the interpretation of the regulations of the Technical Commission should be adopted.

Article (13) The concerned authority should develop a plan to implement all provisions of these regulations to include the stages of application and resources required to implement them, and should not exceed the duration of this plan for three years from the date of application of these regulations.

Table 1: Classification of the treated wastewater according to its quality

(PSI, TR-34, 2012)

Maximum limit for physical, chemical and biological properties *)		Quality of Treated Wastewater			
		High quality (A)	Good quality (B)	Medium quality (C)	Low quality (D)
1.	Potential of Hydrogen pH	6-9	6-9	6-9	6-9
2.	Dissolved Oxygen DO	> 1	> 1	> 1	> 1
3.	Biochemical Oxygen Demand BOD_5	20	20	40	60
4.	Chemical Oxygen Demand COD	50	50	100	150
5.	Total Suspended Solids TSS	30	30	50	90
6.	Total Dissolved Solids TDS	1200	1500	1500	1500
7.	Nitrate Nitrogen NO_3-N	20	20	30	40
8.	Ammonium Nitrogen NH_4-N	5	5	10	15
9.	Total Nitrogen T-N	30	30	45	60
10.	Phosphate Phosphorus PO_4-P	30	30	30	30
11.	Fat, Oil and Grease	5	5	5	5
12.	Phenol	0.002	0.002	0.002	0.002
13.	Detergents MBAS	15	15	15	25
14.	Chloride Cl	400	400	400	400
15.	Sulfate SO_4	300	300	300	300
16.	Sodium Na	200	200	200	200
17.	Magnesium Mg	60	60	60	60
18.	Calcium Ca	300	300	300	300
19.	Sodium adsorption ratio SAR	5.83	5.83	5.83	5.83
20.	Aluminum Al	5	5	5	5
21.	Arsenic As	0.1	0.1	0.1	0.1
22.	Copper Cu	0.2	0.2	0.2	0.2
23.	Iron Fe	5	5	5	5

24.	Manganese Mn	0.2	0.2	0.2	0.2
25.	Nickel Ni	0.2	0.2	0.2	0.2
26.	Lead Pb	0.2	0.2	0.2	0.2
27.	Selenium Se	0.02	0.02	0.02	0.02
28.	Cadmium Cd	0.01	0.01	0.01	0.01
29.	Zinc Zn	2	2	2	2
30.	Chrome Cr	0.1	0.1	0.1	0.1
31.	Mercury Hg	0.001	0.001	0.001	0.001
32.	Cobalt Co	0.05	0.05	0.05	0.05
33.	Boron B	0.7	0.7	0.7	0.7
34.	Cyanide CN	0.05	0.05	0.05	0.05
35.	Fecal coliforms (colony/100 mL)	200	1000	1000	1000
36.	Bacteria E. coli (Colony/100 mL)	100	1000	1000	1000
37.	Nematodes (Eggs/L)	≤ 1	≤ 1	≤ 1	≤ 1

*) All units are in mg/l otherwise stated.

References:

- Law 7/1999: The Palestinian Environmental law, 1999.
- Law 3/2002: The Palestinian Water Law, 2002.
- Law 2/2003 : Agricultural Law ,2003
- Agreements with Israel, particularly the Memorandum of Understanding (MOU) of December 2003
- PS 742/2003: The Palestinian Treated Wastewater Standards, 2003.
- MoA Instructions/2011: The Ministry of Agriculture instructions for treated wastewater reuse in agriculture, 2011.
- TR 34/2012: Technical Regulations for the reuse treated wastewater in agricultural irrigation (PSI, TR-34, 2012)
- The Palestinian Water Law 2014.

Annex 4: Tests' results of the TWW of Jenin's WWTP

All Tests were obtained from N. Atari (Personal communication, August 12, 2022).

No. of Test/ Year	**Figure Title**
Tests 1 – 2/ Mar., 2014 – May, 2015	**Figure A4-A.** Tests' results of the TWW (tests 1, 2) in **2014 & 2015** by Water & Environmental Studies Institute (WESI), An-Najah National University, Nablus, Palestine / on ANERA's request (N. Atari, Personal communication, August 12, 2022)
Test 4/ 2016	**Figure A4-B.** Test's results of the TWW in **2016** by National Agricultural Research Center – Beta Lab. Directorate, Nablus, Palestine (N. Atari, Personal communication, August 12, 2022)
Test 5/ Sep. 2020	**Figure A4-C.** Test's results of the TWW in **2020** by National Agricultural Research Center – NARC Lab., Jenin, Palestine (N. Atari, Personal communication, August 12, 2022)

Test	Unit	Result				
		Sample date 5/5/2015				
		Inlet	After Grit	out let from Pond #1	out let from Pond #2	out let
BOD	ppm	486	427	189	151	113
COD	ppm	755.2	243.2	81.6	49.6	4.8
TSS	%	0.66	0.952	0.765	0.872	0.06
TDS	mg/L	660	679	594	592	692
pH	---	6.8	6.97	7.27	7.05	7.13
Alkalinity (HCO^-_3)	ppm	100	510	260	230	235
Nitrate	ppm	181.6	225.9	1772	57.6	47.4
Ammonia	ppm	92.5	138.79	32.057	7.04	42.7
TKN	ppm	76.2	114.3	26.4	5.8	35.17
PO_4	ppm	343.48	225.35	217.93	194.94	104.55
Total Phosphore	ppm	112.03	73.5	71.08	63.58	34.1
EC	µS	1027	1063	930	927	1102
Turbidity	NUT	100	61	11	11	5
Total coliform	MPN/100ml	4.6x10^5	>1.1x10^4	2.4x10^3	2.4x10^4	2.3x10^2
Fecal coliform	MPN/100ml	1.2x10^3	1.2x10^3	2.3x10^2	1.5x10^3	2.3x10^2
E. coli	MPN/100ml	1.1x10^2	<30	<30	40	<30

Test	Unit	Result				
		Sample date 15/6/2015				
		Inlet	After Grit	Pond #1	Pond #2	Pond #3
Electrical Conductivity	µS	1692	2140	1879	1671	2080
TDS	mg/L	1150	1456	1277	1135	1427
Turbidity	NUT	3	27	7.5	2	41
Nitrate	ppm	131.128	137.33	6.645	91.701	168.43
PH		7.26	7.04	7.76	7.02	6.94
Alkalinity (HCO^-_3)	ppm	255	620	525	205	575
TSS	%	0.0085	0.099	0.048	0.095	0.089
PO_4	ppm	88.9	147.8	91.6	177.83	116.2
TKN	ppm	21.3	122.2	61.97	37.18	113.3
NH_4	ppm	27.32	157.07	79.68	47.8	145.76
Total P	ppm	29	48.2	29.88	58	37.7
Fecal coliform count	MPN/100ml	9.3x10^2	1.5x10^4	1.1x10^4	1.5x10^3	1.2x10^4
Total coliform count	MPN/100ml	2.1x10^3	1.1x10^6	1.1x10^4	1.5x10^3	1.5x10^4
E.coli	MPN/100ml	<30	1.5x10^4	1.1x10^4	1.5x10^3	1.2x10^4

Test	Unit	Result	
		Sample date 13/3/2014	
		Influent	Effluent
BOD	mg/l	510	16
COD	mg/l	1760	128
TSS	mg/l	378	26
TDS	mg/l	1508	1428
Nitrate (NO3-N)	mg/l	13	11
Total - kjeldahl-N	mg/l	399	353.6
Lead (pb)	mg/l	0.1	0.09
Fecal coliform	Cfu/ml	27,100	15
E.coli	Cfu/ml	26,600	14
Nematodes(Eggs/L	Eggs/L	1600	200

20/10/2015

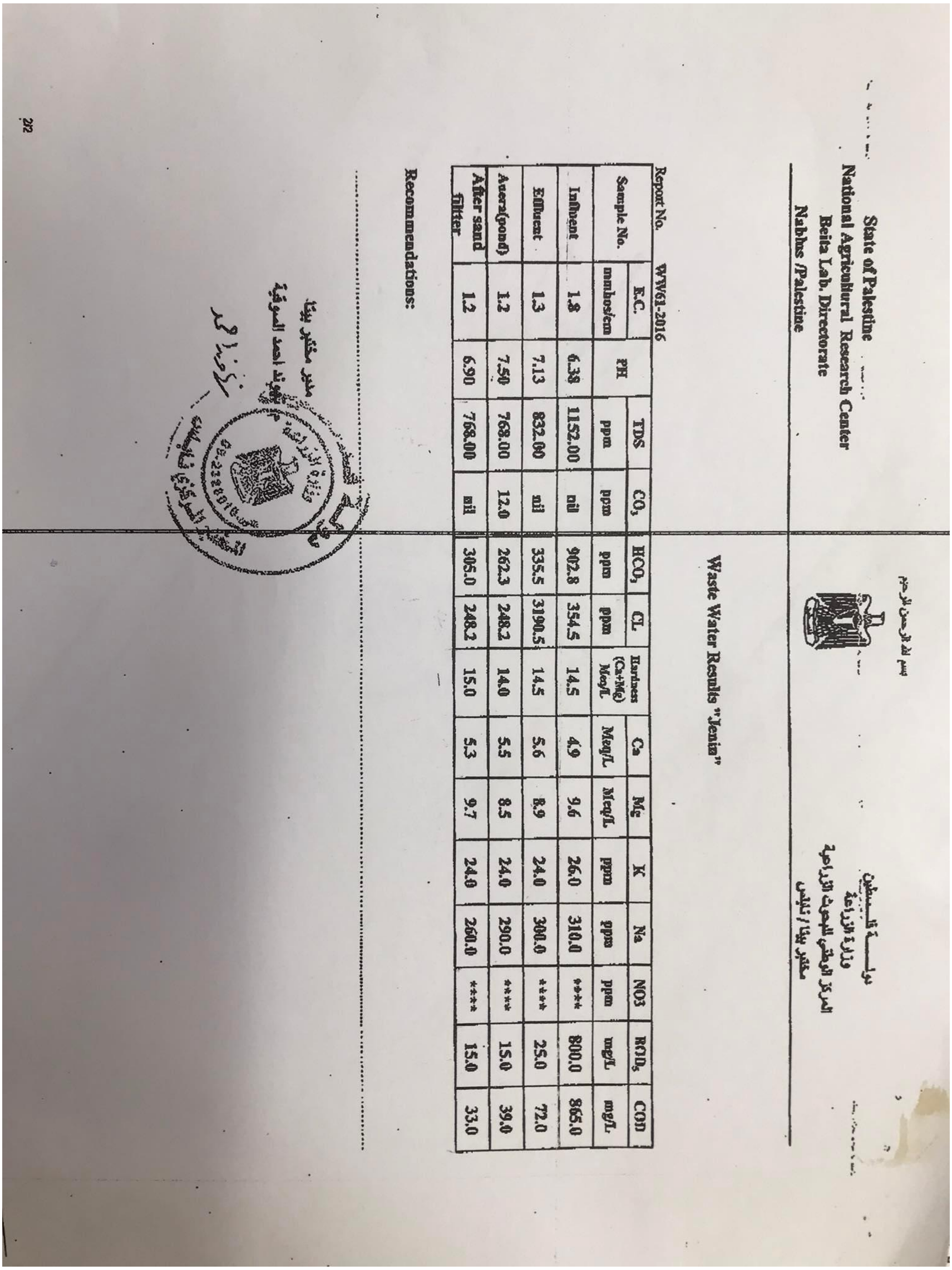
BOD_5 = 32.

COD = [illegible]

ANERA

أنيرا

Figure 4-A. Tests' results of the TWW (tests 1, 2) in **2014 & 2015** by Water & Environmental Studies Institute (WESI), An-Najah National University, Nablus, Palestine / on ANERA's request (N. Atari, Personal communication, August 12, 2022)



بسم الله الرحمن الرحيم

دولة فلسطين
وزارة الزراعة
المركز الوطني للبحوث الزراعية
مختبر بيتا / نابلس

State of Palestine
National Agricultural Research Center
Beita Lab. Directorate
Nablus /Palestine

Waste Water Results "Jenin"

Report No. WW61-2016

Sample No.	E.C.	PH	TDS	CO_3	HCO_3	CL	Hardness (Ca+Mg)	Ca	Mg	K	Na	NO3	BOD_5	COD
	mmhos/cm		ppm	ppm	ppm	ppm	Meq/L	Meq/L	Meq/L	ppm	ppm	ppm	mg/L	mg/L
Influent	1.8	6.38	1152.00	nil	902.8	354.5	14.5	4.9	9.6	26.0	310.0	****	800.0	865.0
Effluent	1.3	7.13	832.00	nil	335.5	3190.5	14.5	5.6	8.9	24.0	300.0	****	25.0	72.0
Aaera(pond)	1.2	7.50	768.00	12.0	262.3	248.2	14.0	5.5	8.5	24.0	290.0	****	15.0	39.0
After sand filter	1.2	6.90	768.00	nil	305.0	248.2	15.0	5.3	9.7	24.0	260.0	****	15.0	33.0

Recommendations:

مدير مختبر بيتا

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Figure 4-B. Test's results of the TWW in **2016** by National Agricultural Research Center – Beta Lab. Directorate, Nablus, Palestine (N. Atari, Personal communication, August 12, 2022)

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بسم الله الرحمن الرحيم

State of Palestine Ministry of Agriculture National Agricultural Research Center	دولــــــة فلسطين وزارة الزراعة المركز الوطني للبحوث الزراعية

تقرير نتائج فحص عينه (ماء و تربة ومحسنات التربة)

(ب) المنتج	
مياه معالجة	اسم المنتج
سائل	نوع المنتج
محطة جنين	مكان اخذ العينه
ناصر عطاري	اسم الشخص أخذ العينه
8/9/2020	تاريخ اخذ العينه
1 لتر	وزن/حجم العينه
7	عدد العينات

(أ) مقدم الطلب	
مديرية زراعة جنين	م المؤسسة صاحب العينه
ناصر عطاري	شخص المكلف
1	د صفحات التقرير
(ج) محلل العينه	
NARC/ قباطيه-جنين	م وعنوان المؤسسة
جابر العمور	م الفني
8/9/2020	يخ استلام العينه
/9/2020	يخ تحليل العينه

(د) نتائج تحليل العينه:

طريقة التحليل/ملاحظات	النتيجة							الوحدة	الفحص	
	7	6	5	4	3	2	1			
pH meter	8.11	8.09	8.18	8.19	8.19	8.21	8.22	****	pH	حموضة
Ec meter	0.78	0.76	0.77	0.75	0.75	0.85	0.85	ms	Ec	لوحة
Titration	11.0	11.2	****	****	****	10.2	10.5	Meq/l		سورة
Titration	114	120	****	****	****	120	124	ppm	Ca	لسيوم
Titration	63.6	62.4	****	****	****	50.4	51.6	ppm	Mg	غنيسيوم
Titration	329.7	322.6	****	****	****	365.2	372.3	ppm	Cl	لور
Flame photometer	26	28	****	****	****	30	30	ppm	Na	سوديوم
Flame photometer	26	29	****	****	****	30	28	ppm	K	وتاسيوم
Cod meter	55	75	****	****	****	284	198	ppm	CO	
Culture	$29*10^{2}$	$31*10^{2}$	****	****	****	$35*10^{3}$	$38*10^{3}$	CFU	Total colifor	
Culture	220	245	****	****	****	$19*10^{2}$	$21*10^{2}$	CFU	E co	

* هذه النتائج تخص العينه المفحوصة فقط ولا يجوز اصدار هذا التقرير الا بموافقة خطية من المركز.

ملاحظة : لما كانت النتائج في العينات متقاربة جدا تم فحص بعض الفحوصات لبعض العينات كما هو موضح في جدول النتائج.

Figure 4-C. Test's results of the TWW in **2020** by National Agricultural Research Center – NARC Lab., Jenin, Palestine (N. Atari, Personal communication, August 12, 2022)