Faculty of Graduate Studies

Master Program in Water and Environmental Engineering

Cost-Benefit Analysis of Beneficial Uses of Reclaimed Water: Three Case Studies from Palestine

تحليل تكاليف و منافع إعادة إستخدام المياه المعالجة ـ ثلاث حالات دراسية من فلسطين

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Dedication

This Thesis is dedicated to my beloved family, and parents for their endless love, support, and encouragement.

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Foremost, I would like to express my sincere gratitude to my advisor Dr. Eng. Rashed Al-Sa`ed for the continuous support of my master study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis.

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Abstract

Beneficial uses of reclaimed water have been considered as an integral part of available water resource in arid and semi-arid regions, like Palestine. Diverse wastewater treatment technologies installed in Palestinian urban centers, availability of land, administrative, socio-economic and environmental issues have impediments on launching sustainable effluent reuse schemes. Existing literature underlined the economic issues of using reclaimed water but ignored the real value of diverse treated water quality, quantity and the non-monetary costs and benefits. This research aimed at studying the cost/benefit (CB) analysis (CBA) of selective beneficial uses of reclaimed water. Three wastewater treatment plants (WWTPs) serving Alteereh-Ramallah (MBR facility), Al-Taybeh and Rammun (RBC system) and Anza (Activated sludge) form case studies for the CB analysis of diverse reclaimed water quality.

The 10 years net present values of CBA for reclaimed water reuse projects in irrigation for three case studies were 5,172,963 (NIS) for Alteereh, 1,150,380 (NIS) for Anza and 1,294,206 (NIS) for Al-Taybeh and Rammun reclaimed water reuse projects in irrigation. The C/B ratio for the reclaimed water reuse projects were 5.04 for Alteereh, 2.55 for Anza and 1.94 for Al-Taybeh and Rammun.

For Al-Taybeh and Rammun reclaimed water reuse project in concrete mixing industry, it showed low NPV and C/B ratio, which indicates that the reuse of reclaimed water in irrigation have more benefits due to the socio-political and environmental benefits involved in the agriculture projects in Palestine.

From the results obtained, it was noted that the reuse project associated with high reclaimed water quality, has higher NPV and B/C ratio, which indicates that choosing higher WWTP technologies is more justified.

To ensure the sustainability of reclaimed water reuse projects, public consultation, awareness raising campaigns and governmental subsidization should accompany the reuse projects.

Variable CBA data were obtained considering the treatment technologies applied, reclaimed water quality and quantity, and the availability of agricultural land. Hence, CBA for planned reuse projects should be evaluated on a case by case basis.

Further studies are needed to explore costs minimization and benefits maximization, using renewable energy and choosing the high value crops.

الخلاصة

تعتبر الاستخدامات المفيدة للمياه المعالجة جزء لا يتجزأ من الموارد المائية المتاحة في المناطق القاحلة وشبه القاحلة، كما في فلسطين. تنوع تقنيات معالجة المياه العادمة المستخدمة في المدن الفلسطينية و محدودية توفر الاراضي المتاحة والقضايا الادارية والاجتماعية والاقتصادية تعمل كعائق على إطلاق خطط مستدامة لإعادة استخدام المياه المعالجة. عالجت الادبيات السابقة القضايا الاقتصادية لإعادة استخدام المياه المعالجة ولكنها اهملت القيمة الحقيقية لتنوع جودة المياه المعالجة و كمياتها و للتكاليف والمنافع غير النقدية. يهدف هذا البحث لدراسة تحليل التكاليف والمنافع لاعادة استخدام المياه المعالجة في استخدامات منتقاه. تم دراسة ثلاث محطات لتنقية المياه العادمة وهي محطة تنقية المياه العادمة في الطيرة (تستخدم تقنية اغشية التفاعل الحيوية) ومحطة معالجة المياه العادمة في قرية عنزة (تستخدم تقنية الحمأة النشطة) و محطة معالجة المياه العادمة في قريتي الطيبة ورمون (مفاعلات التنقية البيولوجية الدواره). حيث شكلت هذه المحطات الثلاث دراسة واقعية للتكاليف والمنافع لإعادة استخدام المياه المعالجة بعدة انواع من الجودة.

بينت نتائج الدراسة ان صافي القيمة الحالية لمشاريع اعادة استخدام المياه المعالجة في الري الزراعي لمدة عشر سنوات هي كالاتي: 5,172,963 (شيكل) لمشروع اعادة المياه المعالجة من محطة الطيرة و 1,150,380 (شيكل) لمشروع اعادة المياه المعالجة من محطة قرية عنزة و 1,294,206 (شيكل) لمشروع اعادة المياه المعالجة من محطة الطيبة ورمون.

بينت نتائج الدراسة ان نسبة المنافع الى التكاليف لمشاريع اعادة استخدام المياه المعالجة في الري الزراعي للمحطات الثلاث كالآتي: 5.04 لمشروع اعادة المياه المعالجة من محطة الطيرة و2.55 لمشروع اعادة المياه المعالجة من محطة قرية عنزة و1.94 لمشروع اعادة المياه المعالجة من محطة الطيبة ورمون.

كما بينت الدراسة عدم جدوى اعادة استخدام المياه المعالجة من محطة الطيبة ورمون لتصنيع الباطون الجاهز وذلك بسبب القيمة المنخفضة لصافي القيمة الحالية ونسبة المنافع للتكاليف في المشروع، ويعتبر

هذا مؤشر الى ان مشاريع اعادة استخدام المياه المعالجة في الري الزراعي اكثر منفعة منها في استخدامها للاغراض الأخرى، وذلك بسبب المنافع الاجتماعية والسياسية والبيئية المصاحبة لمشاريع الري الزراعي في فلسطين.

تبين من الدراسة انه كلما زادت جودة المياه المعالجة، زادت قيمة المشروع الحالية و ايضا زادت قيمة المنافع للتكاليف، مما يدل على الحاجة لاختيار طرق المعالجة المتقدمة من اجل تحقيق اعلى منافع. هذا من اجل ضمان استمرارية مشاريع اعادة استخدام المياه المعالجة، لا بد من عمل استشارات للعامة و عمل حملات زيادة الوعي في موضوع اعادة استخدام المياه المعالجة، ولا بد ايضا من توفر الدعم المادي الحكومي لتشغيل هذه المشاريع.

تم الحصول على عدة قيم لتحليل المنافع والتكاليف في مشاريع اعادة استخدام المياه المعالجة، نتيجة لاختلاف طرق معالجة المياه العادمة المستخدمة، و جودة وكمية المياه المعالجة، و توفر الاراضي الزراعية، لذلك لا بد من دراسة هذه المشاريع كل حالة على حدا. في النهاية مشاريع اعادة استخدام المياه المعالجة بحاجة الى دراسات مستقبلية، من اجل تقليل التكاليف وزيادة المنافع، عن طريق استخدام الطاقة المتجددة لتوليد الطاقة الكهربائية لتشغيل المشروع، ودراسة اي من المحاصيل يعطي مرابح اعلى.

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List of Abbreviations

AMBR	Alteereh MBR Wastewater Treatment Plant
ASTM	American Society for Testing and Material
AWWTP	Anza Wastewater Treatment Plant
BOD	Biological Oxygen Demand
C/B	Cost to Benefit
CBA	Cost to Benefit Analysis
FC	Fecal Coliform
MBR	Membrane Bio Reactor
MoA	Ministry of Agriculture
NPV	Net Present Value
O&M	Operation & Maintenance
PCBS	Palestinians Central Bureau of Statistics
PE	Poly Ethylene
PSI	Palestine Standards Institute
PTWW	Primary Treated Wastewater
PWA	Palestinian Water Authority
SA	Sensitivity Analysis
STWW	Secondary Treated Wastewater
Total-N	Total Nitrogen
TP	Tap Water
TRWWTP	Al Taybeh and Rammun Wastewater Treatment Plant
TSS	Total Suspended Solids
TTWW	Tertiary Treated Wastewater
WB	West Bank (Palestine)
WTA	Willingness To Accept
WTP	Willingness To Pay
WWTP	Wastewater Treatment Plant

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1. CHAPTER ONE
INTRODUCTION

1.1 Overview

Worldwide, treated wastewater[1]or reclaimed water is considered as an additional water source. Reclaimed water can be used in diverse beneficial uses in agricultural, industrial, and recreational sectors.

Un-use of reclaimed water is equivalent to wastewater considering the value and impacts of both technical terms. Therefore, efficient use of reclaimed water is crucial for economic growth and sustainable development of Palestinian communities. Extensive local literature has identified the main challenges and perspectives of reclaimed water use in many water development projects in Palestine. The main challenges and perspectives are summarized as follows:

- Palestinian limited access to available water resources impaired by Israeli hydro-politics via state power and military orders on management of groundwater aquifers (Shuval, 1999; Zeitoun, 2008).
- Groundwater pollution and unbalanced distribution of annual rainwater fall (Almasri, 2007), make direct or indirect aquifer recharge with reclaimed water essential.
- Increase in sanitation service provision by establishing wastewater treatment facilities with annual increase in reclaimed water volumes suitable for beneficial uses (WB, 2004; McNeill et al., 2009; Deek et al., 2010; Al-Sa`ed and Tomalaih, 2011).

[1]Treated wastewater, treated effluent are used interchangeable with reclaimed water considering level of current treatment technology, valid water quality standards and planned intended use

- Reclaimed water has agronomic values important for agricultural productivity (Abu Madi and Al-Sa`ed, 2009; Mizyed, 2013). Thus, reuse comprises a crucial element within the Palestinian national water strategy.

- Beneficial uses form a safe disposal path of treated wastewater. Thus, reduce environmental and public health risks (MEDAWARE, 2005)

- Palestine has set effluent quality regulation and strict agricultural reuse standards, where communities lack the financial and technical capacity to implement a safety control system for agricultural produce irrigated with reclaimed water (PSI, 2012; PWA, 2013).

Wastewater treatment technologies installed in Palestine vary from one district to other. This is due to donors influence and design engineer, where the local legal authorities and communities have less impact during the technology selection. Installing different types of treatment technologies leads to the production of reclaimed water of variable quality. The current challenge facing the sanitation sector in Palestine is not linked to technology type or selection but more to an effective and multifunctional uses of reclaimed water for beneficial uses (Al-Sa`ed, 2014).

1.2 Goals and Objectives

The main goal of this research study is to carry out a cost/benefit analysis (CBA) of reclaimed water value considering the economic, socio-political and environmental factors. The economic factors entail direct, indirect, fixed and O&M costs and the financially benefits. On the other hand, the social costs will measure the willingness to pay for service provision and the environmental cost will include the costs for environmental damage and costs of control and monitoring.

The main objectives of this study are:

- Determine the beneficial uses for diverse reclaimed water quality in three WWTPs, as case studies.

- Determine the non-market values controlling the reclaimed water reuse and measuring the socio-political and environmental issues for the reclaimed water.

- Determining the actual economical values for the reclaimed water reuse.

In Palestine, municipal and domestic wastewater treatment plants produce increased amounts of reclaimed water without being used. Discharge of treated effluent of variable quality unused into wadis and coastal areas forms an economic value loss and threatens the receiving water bodies and public health. Therefore, understanding the multi-variant value of reclaimed water as a new water source in agricultural, industrial or landscaping purposes, a systematic assessment tool is needed. Awareness campaigns for stakeholders (people, farmers, investors) are essential for maximizing the economic and political benefits of the reclaimed water for beneficial uses (GWP, 2014).

1.2.1 Research Questions

The need for local case studies that include the costs and benefits involving in the beneficial uses of the reclaimed water is essential to clarify the best application techniques and policy directions that promote economic growth and enhance community development.

The main research questions revised by this study are:

- What effluent quality allows for beneficial uses and what impacts does it have on the value of beneficial uses of reclaimed water?

- What is the actual economic value (net benefits) and how to calculate for beneficial uses of reclaimed water?

- How socio-political and environmental issues play a role in reclaimed water reuse projects appraisal?

Aside from political issues, the limited access to water resources in Palestine urges pressure at the people, farmers, investors and decision makers. Provision of sewerage networks and wastewater treatment plants increased sanitation services result in annual increase of produced wastewater, thus treated wastewater of variable effluent quality. Increased agricultural demand with variable rainwater fall imposes negative impacts on soil fertility (salinization) and lowers water quality (salt intrusion), as the case in Gaza Strip. Lack of knowledge and understanding of the real values of reclaimed water hampered successful implementation of full scale reuse schemes.

Analysis and identification of beneficial uses considering the value of reclaimed water is needed. A systematic framework and tools for measuring the market and non-market determinants are crucial elements while opting for any current or planned wastewater reuse project. The Palestinian water strategy incorporated reuse of recycled water in an integrated water management, where beneficial uses in agriculture, industry, recreation, landscape and artificial water recharge are underlined. This study envisages exploring the cost/benefit analysis to calculate the market and non-market values of reclaimed water use considering variable degrees of treatment levels, volumes, availability of land, and reuse type.

1.3 Thesis Outline

Chapter Two: Literature review

This chapter revises the previous practices of reclaimed wastewater reuse in the world and Palestine. Also revises the costs, benefits, health social and environmental aspects involved in the reclaimed wastewater reuse projects, and clarifies the Palestine standards institute reuse regulations.

Chapter Three: Study area

This chapter lists information about the WWTPs areas, process description water and wastewater quality and quantity.

Chapter Four: Methodology

This chapter discusses the CBA criteria, listing the costs and benefits calculation methods involved in the reclaimed water reuse projects.

Chapter Five: Results & Discussion:

This chapter illustrates the results revealed by this study and gives brief discussion for the results.

Chapter Six: Conclusions

This chapter lists the main conclusions of the study, illustrating the main final results. Finally, chapter seven presents recommendations and further studies needed in the research area.

2 CHAPTER TWO

LITERATURE REVIEW

2.1 Wastewater Reuse

The evolution of wastewater networks at the early of twentieth century caused the search for safe disposal of wastewater, the sewage farms was used as way to remove the wastes from the centers of the towns, incidental use of wastewater in crop production was practiced (Levine, et al., 1996).

In Israel about 630 Mm^3 are reused yearly in irrigation, which is considered as 80% of treated wastewater. The main reuse project implemented by MEKOROT company is the conveying pipeline from Shaf Dan to Negev, where the treated wastewater are recharged to the groundwater aquifer in Shaf Dan, there the treated wastewater are further physically treated and pumped again by about 150 extraction wells, and then transmitted by 70 inch pipeline to be reused in unrestricted irrigation in Negev (MEKOROT, 2014).

In Jordan about 120 Mm^3 of treated wastewater used for irrigation in the Jordan valley area, which is considered as 24% of water used for irrigation in Jordan, where 502 Mm^3 used yearly for irrigation, Asamra WWTP is the main treatment plant in Jordan, which treats about 75% of all wastewater, then the treated effluent flows into King Talal dam, where the treated effluent mixed with fresh water and then used for unrestricted irrigation (Seder, et al., 2011).

Survey implemented in Europe, California, Japan and Australia, showed that in Europe in 2000 about 963 Mm^3/yr was reused of which 70% used in agricultural irrigation and 17% in groundwater recharge. In California about 434 Mm^3/yr. was reused of which 49% for irrigation and 14% for groundwater recharge, while in Japan about 206 Mm^3/yr. of which just 8% for irrigation and 38% for industrial purposes, and in Australia about 166Mm^3/yr of reclaimed water reused of which 30% for irrigation and 40% for industrial reuse purposes, which indicate that the agriculture irrigation is main water consumer for reclaimed water (Hochstrat, et al., 2008).

2.2 Reclaimed Water Reuse Practices in Palestine

There are few reuse activities of reclaimed water in Palestine due to many reasons, but the main objective for the Palestinian water sector is to reuse the reclaimed wastewater in the agricultural activities, as it is considered the main water consumer in Palestine (MERAP, 2010).

Al-Bireh WWTP, which is located in Wadi Al-Ein (south of Al-Bireh city) over 2.2 ha area; and was constructed in 2000, designed to serve more than 100,000 inhabitants. The treatment system used is extended aeration and the plant was designed to treat 5750 m^3/day. Demonstration reuse project was conducted in Al-Bireh WWTP where the reclaimed water was reused in irrigation, and multi wastewater qualities were tested on different types of crops (MEDAWARE, 2005).

Two types of reclaimed water were used in irrigation of trees and crops, high effluent quality and very high effluent quality, orchard trees were planted, including different varieties of olives, date palms, stone fruits, citrus, cherries, mango, avocado, guava, pomegranate, figs and grapes. On an area of 3 dunums indigenous Palestinian trees were irrigated, including nut trees like pistachio, walnut, pecan, macadema, pinenuts, asacia, pines and carob. A parcel of 0.7 dunums was planted with sweet corn. No additional fertilizer was used, Also a nursery of 600 m^2 for annual cultivation of 80,000 seedlings of indigenous trees and cooked vegetables. The results obtained from this experiment showed high crops yield and no contamination from both two types of reclaimed water quality (Mogheir, et al., 2005).

In Jenin district, Al-Jalameh reclaimed wastewater reuse project was implemented by the Near East Foundation (NEF), it targeted about 100 hectares of agricultural lands, providing the farms with reclaimed wastewater from Jenin WWTP, and pumping station was installed in the WWTP to pump reclaimed water to the farms by HDPE pipelines conveying it to agricultural tanks. The implementation of infrastructure works accompanied by training and capacity building for farmers MoA employees and local council workers about the reuse of reclaimed water, many types of trees were planted in this project with different crops market value such as avocado, olives, almonds, mango, apple and peach. The project provided opportunity to plant new irrigated crops, reducing production costs, increasing profits from irrigating rain-fed crops and creating more employment opportunities in the targeted area (NEF, 2015).

Pilot irrigation reuse projects were implemented in Anza and Beit Dajan villages in Jenin and Nablus cities respectively. The reuse of reclaimed wastewater generated from Anza and Beit Dajan WWTPs in irrigation, resulted in increase of the crop quantities and reduction in unproductive years of trees (Anza & Beit Dajan village councils, 2016).

2.3 Wastewater Reuse Costs

The reuse of reclaimed water in irrigation usually involves many monetary costs such as agricultural land costs, reclaimed water treatment costs, pipe works and conveyance system including the storage of reclaimed water (Kihila, et al., 2014).

The main economic costs for the reuse of reclaimed water are; the costs of unsafe use of reclaimed water, which can lead to public health risks or environmental pollution, weak economic analysis which can lead to wrong reclaimed water tariffing and non-recovery of true costs, weak economic analysis which doesn’t consider all the economic opportunities and lead to loss of benefits, high costs of reclaimed water conveyance systems, and lack of local market demand study for the reclaimed water can lead to loss (MEDWWRWG, 2007).

2.4 Wastewater Reuse Benefits

In reference to EPA, there are many environmental benefits related to reuse of reclaimed water such as reducing the diversion of freshwater from sensitive ecosystems, reducing the discharging of wastewater to water bodies, reducing the pollution and enhancing wetlands (EPA, 1994).

According to UNEP report the reclaimed wastewater reuse is very important in the Palestinian Territories and has good potential to be developed for many reasons; the deterioration of groundwater resources quantities, the expansion of sewerage networks, the production of large quantities of reclaimed wastewater which can be available for reuse in irrigation, the nutrient content of wastewater which can reduce the use of fertilizers and the reuse of reclaimed water is considered as safe disposal of wastewater(UNEP, 2000).

Many economic benefits related to reclaimed wastewater reuse such as; the substitution of fresh water in many applications (e.g. irrigation, toilet flushing), provide water source with consistent quality and quantity, which lead to sustained agricultural and industrial production. Enhance the landscape of the urban areas, which can lead to increasing in tourists and cause job creation opportunities, reducing the fertilizers application in agriculture and landscape activities, reducing the investment in new water sources abstraction as it substitutes the fresh water in many applications, this can lead also to increase the fresh water available for the potable uses (MEDWWRWG, 2007).

2.5 Health Aspects of Reclaimed Water Reuse

In Al-Bireh demonstration project strict safety and health practices were conducted, the effluent of good quality and good disinfection system, and using drip irrigation using all personal safety instruments, immunization against typhoid fever and hepatitis A and B among the workers, all these procedures produced safe and healthy use of treated effluent without any harm for the workers (MEDAWARE, 2005).

2.6 Social aspects of Reclaimed Water Reuse

A master thesis by Birzeit student conducted public awareness meetings for the reuse of treated wastewater in targeted villages in West Bank, he found that the farmers willingness to use the treated effluent is raised after the awareness program, where 97% of farmers will reuse the treated wastewater in irrigation, and about 55% of farmers will change the pattern of agricultural lands from rain fed crops (Olives, cereals) to irrigated crops and fruits, so as to increase the income from their lands. (Arafat, 2012)

2.7 Industrial Reuse of Reclaimed Water:

The main industrial use of reclaimed water is in cooling towers, but it needs good treatment so as to prevent the corrosion of the protective coating inside the pipes and to prevent the precipitation of silica and salts at the inner sides of the pipes, also the reclaimed water is widely used in dust control in the infrastructure projects (Huertas, et al., 2006).

Aqel, et al. (2015) tested reclaimed water in concrete mixing process with different qualities but all of them tertiary treatment wastewater (TTWW) taken from four different WWTP in the WB compared to the tap water, all the results were within the limits of the American Society for Testing & Material ASTM standards, and the study concluded that the reclaimed water with different qualities can be reused safely in the concrete mixing industry.

AlGhusain, et al. (2003) measured the suitability of using reclaimed water with different qualities primary treated wastewater, secondary treated wastewater and tertiary treated wastewater (PTTW, STTW and TTWW) compared to the taped water TW. They found that there is some differences in the properties of the concrete samples as the PTWW and STWW showed less strength and higher corrosion for steel, and they found that the TTWW is the most suitable and safe for use in concrete mixing.

2.8 Palestinian Standards for Reuse of Treated Wastewater:

So as to regulate the reuse of treated wastewater, the Palestine Standards Institute (PSI) issued the reuse standard (PSI 742-2003) in 2003. In addition to that, the PSI issued technical obligatory guidelines for agricultural reuse of treated wastewater (34-2012). These guidelines do not allow the use of treated wastewater for irrigation of vegetables or direct groundwater recharge. The guidelines stated that the reuse of treated wastewater in irrigation should be approved by the Ministry of Agriculture. The permits should be given in accordance to the (PSI 742-2003) where the treated effluent is classified into four main categories as in Table 2-1 (Mizyed, 2013).

Table 2-1: Classification of TWW quality in accordance with PSI 742-2003 and PSI34-2012:

Grade	Quality	Description
Grade A	High Quality	BOD_5<20 mg/l, TSS<30 mg/l, FC< 200/100ml
Grade B	Good Quality	BOD_5<20 mg/l, TSS<30 mg/l, FC< 1000/100ml
Grade C	Average Quality	BOD_5<40 mg/l, TSS<50 mg/l, FC< 1000/100ml
Grade D	Low Quality	BOD_5<60 mg/l, TSS<90 mg/l, FC< 1000/100ml

Source: Palestine Standards Institute **(PSI, 2012)**.

The PSI sets number of barriers for every different crop according to the treated effluent quality, for example just the Grade A can be used for landscaping of gardens, sport fields and parks, while crops for seeds can be irrigated without any restriction using all grades. Fruits like apples and peaches can be irrigated with number of barriers using treated wastewater with grades B,C and D, and without any barrier using Grade A. The barriers defined by the PSI for example, the sand filter considered as one barrier, crops eaten cooked considered as one barrier and also subsurface irrigation considered as one barrier. Also other PSI procedures should be implemented before issuing the reuse permit, as the color code for the reuse pipelines (purple), signs indicates that the water is treated wastewater, fencing the lands that using the treated wastewater, availability of freshwater for the farmers in the farms and using all the safety and health equipment by the farmers to minimize health risks (PSI, 2012).

3 CHAPTER THREE

STUDY AREA

3.1 Anza WWTP

3.1.1 General

Anza is a Palestinian village in the Jenin Governorate in the northern West Bank. It is located18 km southwest of Jenin City. According to Palestinians Central Bureau of Statistics (PCBS), the estimated population of Anza is about 2,034 inhabitants in 2010, the total area of Anza, according to PCBS (2007) is about 4,740 dunums, and the total area of Anza, according to PCBS (2007) is about 4,740 dunums. Through a meeting with the head of Anza village council, he declared that some 1,000 dunums owned by the neighboring Ajjah residents were recently bought and added to Anza total area. In the meantime, the built-up area is estimated to be about 700 dunums and used for housing, roads, public and services. See the location of Anza in Jenin District (Anza Village Council, 2015).

Figure 1: Location Map of Anza within Jenin Governorate

The area of the village which is available for potential agricultural activities is estimated at about 5,000 dunums. About 20% of this area is plain land and the remaining 80% is mountainous area. The whole area is unirrigated and hence relies totally on rainwater. The plain area is cultivated with crops like wheat, barley and legume meanwhile the mountainous area is planted mainly with olive trees in addition to prickly pear. A significant part of the mountainous area is considered as wooded trees and shrubs area with great numbers of pine trees (EQA, 2011).

3.1.2 Water and Wastewater Characteristics:

Water consumption based on the population is about160 m^3/d, where 85% of these water flows into the sewerage system and inlet the wastewater treatment plant. However, till now not all the village inhabitants are connected to the wastewater network and the influent flow design is made as 78 l/c/d but the real influent is about 50 l/c/d, so the average daily influent to the WWTP is about 62 m^3/d, table 3-1 illustrates the water consumption and wastewater generation for 25 years horizon **(EQA, 2011)**.

Table 3-1 Quantities of water consumption and wastewater generation in Anza village

Year	Population No.	Water Consumption		Wastewater Production
		l/c/d	M^3/d	M^3/d
2010	2034	78	160	135
2022	2969	100	296	230
2035	4471	100	492	380

The wastewater characteristics inlet to AWWTP are illustrated in Table 3-2 (EQA, 2011):

Table 3-2: AWWTP influent characteristics

Parameter	Unit	Value
BOD_5	Mg/l	530
TSS	Mg/l	530
TN	Mg/l	180
FC (Fecal Coliform)	CFU/100ml	10^7

The WWTP is designed to treat the wastewater to a level that complies with the PSI agricultural reuse standards and as illustrated in Table 3-3 (EQA, 2011):

Table 3-3: AWWTP designed effluent characteristics.

Parameter	Unit	Value
BOD_5	Mg/l	<30
TSS	Mg/l	<30
TN	Mg/l	<50
FC (Fecal Coliform)	CFU/100ml	<1000

3.1.3 Anza WWTP Process Description:

In 2014 The Palestinian Agricultural Relief Committees (PARC) implemented a wastewater collection system, wastewater treatment plant and reclaimed water reuse system which was funded by European Union as part of the "*produce more food through sustainable and safe use of reclaimed wastewater in agriculture*" project. The technology used in wastewater treatment is the activated sludge with sludge aerobic stabilization.

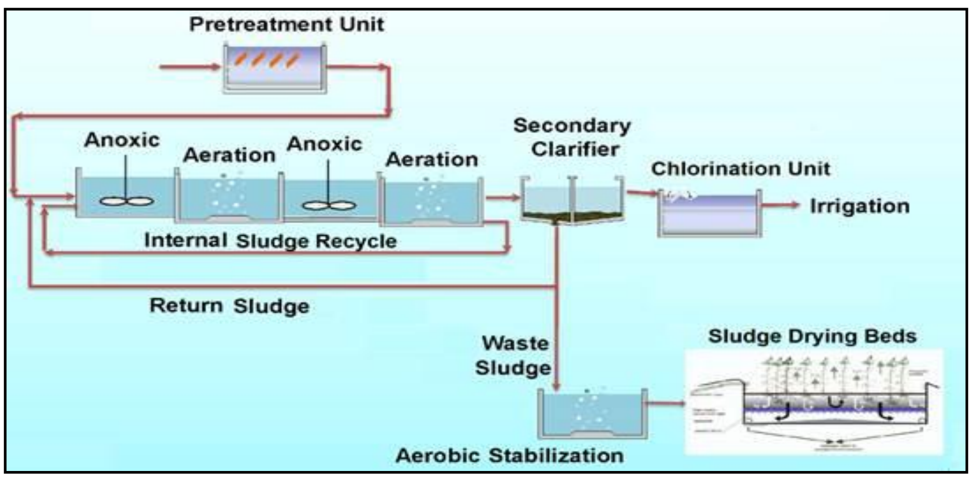

Figure 2: Schematic process flow diagram for AWWTP.

As shown in Figure 2, the treatment process includes three stages primary, secondary and tertiary treatment:

- Primary treatment: the wastewater main trunk line carries the wastewater to the influent pumping well, where it is flows through three main elements:

1- Manual bar screen: first the wastewater reaches the manual bar screen to prevent the materials with size 1cm or above from entering the WWTP which can cause harm to the pumping stations and the following devices.

2- Grit and grease removal chamber (Figure3): to sediment sand particles in the bottom of the chamber then it is drawn to waste container using screw pump, then using air compressor the flowing air prevents the grease and scum from sinking into the bottom of the tank and make them floating on the surface, then they can be removed using scrapper and drawn to the waste container using screw pump.

3- Automatic fine screen (Figure3): all the fine particles with size 0.3mm or above are removed using rotary fine screen, where all the waste can be drawn to the waste container using the screw pump.

Figure 3: Complete pretreatment unit in AWWTP.

➢ Secondary treatment: includes the biological treatment in the activated sludge tank, and the sludge separation in the secondary sedimentation tank

1. Activated sludge (AS) tank: after completing the pretreatment the wastewater flows by gravity into the activated sludge tank, where the biological treatment

starts, the AS tank includes four rooms(Figure4), the first one anoxic with mixer to prevent the settling of the MLSS and to insure the suspension and contact of the MLSS with the bacteria, the second room is oxic zone with air diffusers where two air compressors supply the diffusers with oxygen which is utilized by the aerobic bacteria to convert the ammonia into nitrate (nitrification), then to anoxic with Dissolved Oxygen (DO) meter to control the operation of the air compressors and to optimize the electrical consumption at this room the facultative bacteria convert the nitrate into nitrogen gas (denitrification) , and finally to the oxic zone where part of the wastewater pass through the outlet to the secondary settling tank, and the other part returns as internal recirculation.

Figure 4: The AS Tank in AWWTP

2. Secondary settling (sedimentation) tank (Figure5): its main role is to separate the AS from the liquid, as the AS settles and sediments at the bottom of the tank where is sludge pump returns ratio of the settled sludge into the anoxic

zone in the AS tank, and the other sludge is pumped to the sludge holding tank, the water through channels up of the tank into the chlorination tank.

Some of the unsettled matters float on the tank surface where automatic scrapper removes and gather them in scum manhole, then using sludge pump removes them to the sludge holding tank.

Figure 5: Secondary Settling (sedimentation) Tank at AWWTP.

- Tertiary treatment: the water exits the secondary settling tank flows into the chlorine disinfection tank, where is the liquid chlorine being injected using dose pump in certain ratio, then the water flows into the treated water tank, then using pump it flows to the agricultural reuse tank, where the water can flows by gravity to the agricultural lands.

- Sludge treatment: the waste sludge which is pumped from the secondary sedimentation tank and scum manhole should be stabilized and treated, using the sludge holding tank and reed beds:

    1. Sludge holding tank (Figure6): as illustrated before the excess sludge pumped to the sludge holding tank, where the sludge is aerobically stabilized by the bacteria which got its needed oxygen by the air

diffusers in the bottom of the tank, after completing the sludge stabilization the sludge is pumped using submersible pump to be dried using reed beds.

Figure 6: Sludge holding tank in AWWTP

2. Reed beds (Figure7): the stabilized sludge is dewatered by the reeds which consume some of the liquid, and the other settled part of water flows down the reed beds into water collection system which collect the settled water in tank, then the water which is rich of ammonia pumped into the oxic zone in the AS tank to be treated.

Figure 7: Reed Beds in AWWTP.

3.2 Alteereh WWTP

3.2.1 General

Alteereh Membrane Bio Reactor (AMBR) facility, serving Alteereh suburb of Ramallah city and located in Wadi Ein Qinya, has been recently put into operation (November, 2013). AMBR employs ultrafiltration membranes (GE hollow-fiber membranes of 0.045 micron as nominal bore size) in activated sludge system with separate aerobic sludge digestion. A reclaimed water of stable quality is produced with 10/10/10 (TSS/BOD/Total-N; mg/L). Chlorination unit is installed for reclaimed water disinfection. Despite high quality effluent, it is currently discharged into Wadi Ein Qinya without effective use (GES, 2012).

Figure8 shows the location of the AMBR in Ramallah District.

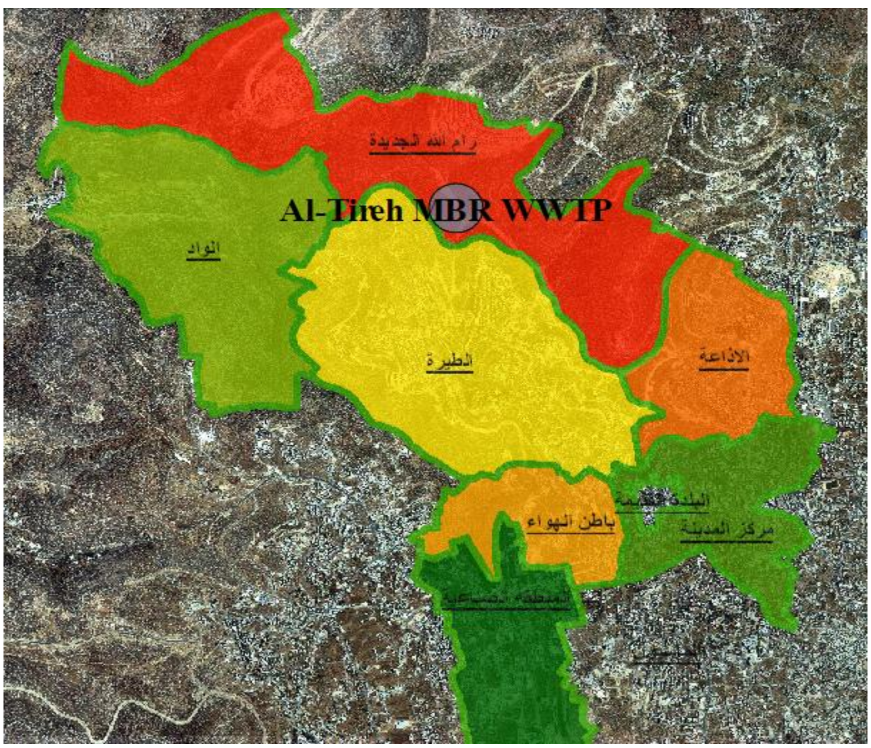

Figure 8: Location map for AMBR WWTP in Ramallah district

3.2.2 Water and Wastewater Characteristics

AMBR WWTP was designed to serve Alteereh neighborhood in Ramallah district with treatment capacity of 2000 m^3/d, the wastewater influent characteristics are illustrated in table3-4 (GES, 2012).

Table 3-4: AMBR influent characteristics.

Parameter	Unit	Value
BOD_5	mg/l	660
TSS	mg/l	400
TN	mg/l	140
FC (Fecal Coliform)	CFU/100ml	10^7

The actual effluent characteristics referring to average values from lab tests are illustrated in table3-5 (GES, 2012).

Table 3-5: AMBR effluent characteristics

Parameter	Unit	Value
BOD_5	mg/l	3
TSS	mg/l	3
TN	mg/l	10
FC (Fecal Coliform)	CFU/100ml	1

The previous results show high treated water quality, which doesn't need further treatment and can be used for unrestricted irrigation.

3.2.3 Alteereh WWTP Process Description

In 2013, Ramallah Municipality implemented wastewater collection network and WWTP for Alteereh neighborhood; they chose a high technology MBR WWTP to get high effluent quality, so as to protect Ein Qenya stream and spring and to use the reclaimed water in unrestricted irrigation in the downstream agricultural lands.

The MBR WWTP consists of three treatment stages:

- Preliminary treatment: As the wastewater flows by gravity through the main trunk line into three main elements , lifting station, odor control and pretreatment unit:

1- Lifting station: the wastewater is screened by the 50mm basket screen in the inlet to the lifting station then the wastewater is lifted to the WWTP through two submersible pumps, one in operation and the second as stand by pump.

2- Head works odor control unit: directly connected to the lifting station, which is ventilated through the odor control which is activated carbon type, where magnesium hydroxide or soda ash dosing is implemented for pH control and consequently odor emissions, such as H_2S reduction.

3- Compact pretreatment unit: its main function is to remove the pollutants that can cause operation and maintenance problems downstream, as the solids, grit and grease.

   The pretreatment package consists of 10 mm coarse screen, grit and grease removal and 1mm fine screen which is necessary for the protection of the membranes, this package is dosed with chemicals for pH control and activated carbon odor control to prevent the malodors.

   The solids are dehydrated to reduce the volume of the solid waste before discharging it in plastic containers then to be transferred and discharged safely in landfill.

- Membrane bioreactor: the technology used is suspended growth biological reactor with an ultra-filtration membrane system.

  The MBR process combines the unit operations of aeration, secondary clarification and tertiary filtration into a single process.

The membranes are of the hollow fiber type, the ultra-filtration system replaces the solids separation functions of secondary sedimentation tanks and the other filters types in conventional activated sludge techniques.

The membranes are immersed in the aeration tank, in direct contact with mixed liquor, suction is applied to header connected the membranes by using permeate pump, where the vacuum forces the wastewater to permeate the hollow fibers in the ultra-filtration membranes, permeate then disinfected or discharged into the stream,

- Bioreactor: the raw sewage is pumped to the suspended growth bioreactor tanks, the wastewater flows through four zones, anoxic, oxic, anoxic and MBR (oxic), these stages create the necessary environment to attain carbonaceous matter removal and to complete the nitrification and denitrification process.

- Tertiary treatment: the effluent and sludge from the WWTP should be safe to reuse, so disinfection system is used to eliminate the pathogens from the effluent, and sludge stabilization system is used to stabilize and reduce the pathogens from the sludge so as to be safe reuse in various applications and to match the responsible authority's standards.

  1- Sludge treatment :two stages of sludge treatment are used first the sludge is aerobically stabilized by the aerobic sludge digestion tank, then the sludge volume is reduced by the sludge dewatering system:

  a- sludge treatment technology used is aerobic sludge digestion, where all the sludge produced from the filtration stages are gathered and sent by the sludge recirculation pumps to the aerobic sludge holding tank, the sludge are treated to reduce pathogens and volatile solids

  b- Sludge dewatering- centrifuge: the sludge dewatering is conducted by a centrifuge with polymer dosing system, then the sludge is transferred to plastic containers using screw conveyor, then the resulted sludge is transferred to the municipality landfill.

2- Disinfection: the treated water effluent from the MBR bioreactor is dosed with calcium hypochlorite by dosing pumps, the dose quantity is controlled automatically by feedback measures from the outlet line, then the effluent is disinfected and is of a standard suitable and safe for reuse applications.

3.3 Al Taybeh and Rammun WWTP

3.3.1 General

Both Al Taybeh and Rammun villages are Palestinian towns in Ramallah District, the towns of Al Taybeh and Rammun are located to the east of Ramallah District, next to the Ein Samia well fields which is known as the most important water supply for Ramallah and Al-Bireh district. Al Taybeh town according to PCBS census of 2007 is 1,452 inhabitants where the average household members are 4.4.

For Rammun town according to PCBS census of 2007 is 2,626 inhabitants where the average household members are 5.6, both towns have actual population growth of 2.6% according to PCBS.

The two villages located at the eastern slopes of the WB being in the eastern basin as well draining toward the east part of the WB toward the Jordan valley area.

Figure 9: Location Map for AL-Taybeh and Rammun towns in Ramallah District.

The people on both towns mainly rely on agriculture and small businesses. However, their economic center is Ramallah city.

3.3.2 Water and Wastewater Characteristics

Using the geometric growth method the predicted population is calculated where 2.6% of average population growth taken into account, for the water and wastewater consumption data were taken from the towns councils where average daily consumption per capita considered to be 60 l/c/d and the predicted wastewater percentage is 80%, the population, water and wastewater characteristics for 20 years horizon were calculated as in the table3-6 (AlTayebeh & Rammun village council, 2012):

Table 3-6: Al-Taybeh and Rammun town's population and water consumption

Year	Population No.	Water Consumption		Wastewater Production m^3/d
		l/c/d	m^3/d	
2007	4078	60	245	196
2015	5008	65	325	260
2035	8367	100	837	669

Table3-7 illustrates the wastewater influent characteristics to the WWTP (AlTayebeh & Rammun village council, 2012).

Table 3-7: TRWWTP influent characteristics

Parameter	Unit	Value
BOD_5	mg/l	500
TSS	mg/l	500
TN	mg/l	180
FC (Fecal Coliform)	CFU/100ml	10^7

The TRWWTP proposed to treat the wastewater to level that match the PSI agricultural reuse standards and as illustrated in table3-8 (AlTayebeh & Rammun village council, 2012):

Table 3-8: TRWWTP proposed effluent characteristics.

Parameter	Unit	Value
BOD_5	Mg/l	20
TSS	Mg/l	30
TN	Mg/l	50
FC (Fecal Coliform)	CFU/100ml	<1000

3.3.3 Al Taybeh and Rammun WWTP Process Description:

Based on comparison analysis performed by the towns council for the wastewater treatment processes, they chose the Rotating Biological Contactor (RBC) treatment process, as it need less lands than the aerated lagoons and wetlands, and the energy costs is low compared to activated sludge, MBR and SBR. The RBC technology is simple to operate compared to other technologies. Figure10 illustrates the schematic process diagram for the TRWWTP.

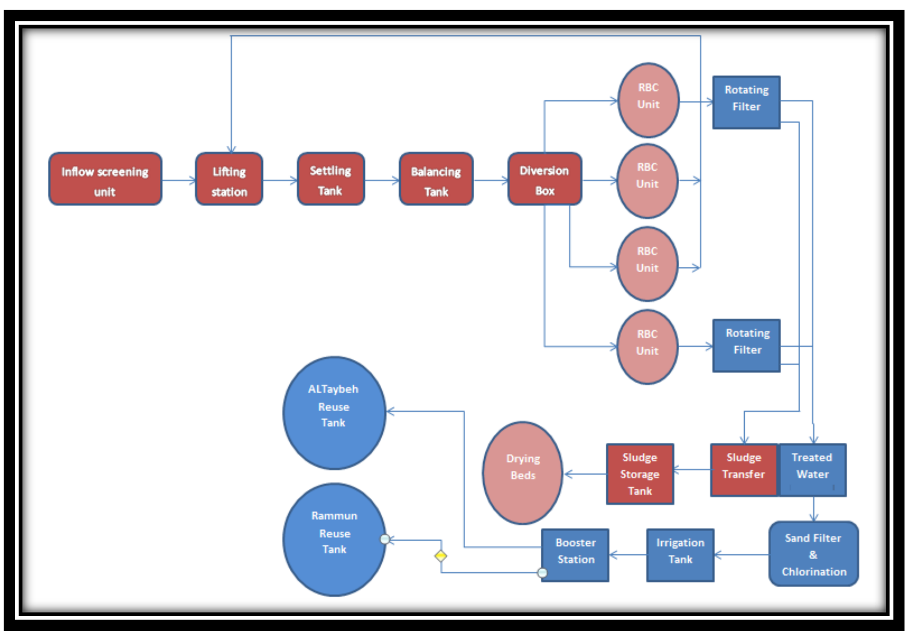

Figure 10: TRWWTP schematic process diagram.

The TRWWTP was designed with capacity of 450 m^3/d, following is the process description stage by stage:

1. The Screening (Figure11): the wastewater flow in through the open front end of the screen basket and through the screen bars. Solids are retained by the screen basket.

Figure 11: Screening unit at TRWWTP.

2. The settling Tank: to improve downstream process and to keep the system equipment undamaged it is important to use the settling tank to prevent the large solids from entering the system, the settling tank is used as primary clarifier and remove a portion of the non-soluble BOD associated with the raw wastewater’s suspended solids, the dissolved waste flows over with the water into the equalization tank.

3. The equalization Tank: after the primary settling the wastewater flows to an equalization tank that controls the hydraulic velocity (flow rate), the equalization of flow prevents short term, high volumes of incoming flows from forcing solids and organic material out of the treatment process, also controls the flow through each stage of the treatment system, allowing adequate time for physical , biological and chemical processes to take place then the wastewater flows to the biodisk streams for biological treatment stage.

4. The Flow Divider: in the flow divider the water from the equalization tank is controlled in its volume, if too much water then it will flow back to the equalization tank; the other water will be divided into four streams going by gravity to the biodisks.

5. RBC Units (Figure12): the RBC units installed in halls with sufficient ventilation and low light exposure, as many biodisks lines as necessary connected in parallel and fed by a flow divider. Bio-degradable, organic contaminants are absorbed by the organisms covering the immersed section of the discs and by the activated sludge in the immersion tanks, then they are converted to activate substances. Oxygen needed for oxidation is absorbed by the micro organic coating on the discs during the phase in which it is exposed to the surrounding air, the oxygen on the disc surface is diffused and then penetrates to the deeper layers of the micro organic coating. At a rate of 4-5 rpm, the amount of oxygen generated is normally high that in spite of continuous oxygen consumption by the microorganisms and sludge in the tanks, the average oxygen content is about 2-3 mg/l.

Figure 12 : (RBC) Units at TRWWTP.

6. The Rotating Filter (Figure13): the biologically treated water leaving the biodisks contains suspended organic material and fragments of bio film, which periodically break off from the disks.

Figure 13: Rotating filter at TRWWTP.

After biological treatment water flows through the drum filter while sludge is collected on the drum and regularly back washed by a pump. Both sludge and water flows gravitationally in this process.

7. The sludge treatment: the separated sludge flows out of the drum filters and stored in anaerobic digestion reservoirs for volume reduction, the sludge is collected from the sludge tank and placed on sand drying beds for dewatering (Figure14).

Figure 14: Drying Beds at TRWWTP.

8. The sand filter and disinfection unit (Figure15): the treated effluent goes through sand filter to reduce the TSS content in the water and then being disinfected by chlorination unit to reduce the fecal coliform and the other dangerous contaminants.

Figure 15: Disinfection unit at TRWWTP.

9. The Reuse of treated water: the treated water flows by gravity into storage tank then pumped by two separate pumps to the towns (Figure16), for every town it has its own pump and also reuse tanks (steel tanks) in the towns, so the treated effluent can be used to irrigation.

Figure 16: Reclaimed water pumps for Reuse in TRWWTP.

3.3.4 Actual Effluent Water Characteristics:

Actual effluent tests results were taken for various months Table 3-9 shows the average tests results (AlTayebeh & Rammun village council, 2012).

Table 3-9: Actual effluent water characteristics for TRWWTP

Parameter	Unit	Value
BOD_5	mg/l	35
TSS	mg/l	60
TN	mg/l	114
FC (Fecal Coliform)	CFU/100ml	76

The previous results show good BOD and TSS removal, but for the total nitrogen it shows that it is relatively higher than the influent, due to the nitrification of the ammonia to nitrate without completing the denitrification stage, where denitrification occurs partially in RBC and usually in the initial stages of the RBC where high heterotrophic bacteria concentration and anoxic environment available (Prashant, et al., 2012), as it needs anoxic zone which is not available in the current WWTP, so modification should be done for the process so as to complete the denitrification stage, many literatures discuss the RBC modification to increase the nitrogen removal efficiency.

Alonso, et al. (2010) suggests to install mobile bed reactor before the RBC units, and to increase the recirculation ratio between the RBC and the mobile reactor which is anoxic reactor, Figure17 shows the schematic diagram that illustrates the new suggested process.

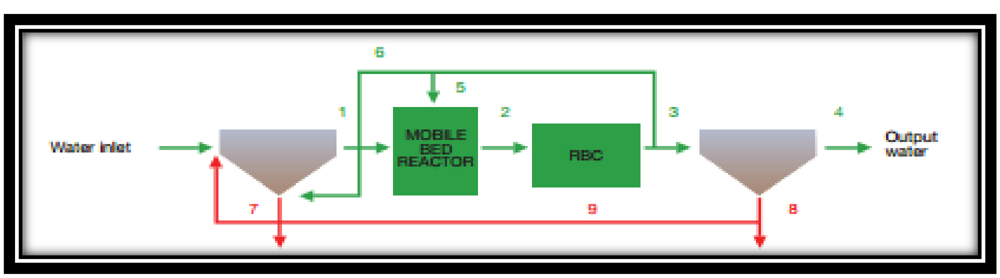

Figure 17: Schematic diagram for the RBC reactor by Alonso.

They found that the anoxic reactor made the system more robustness as it keeps the efficiency removal of the BOD and COD about 86%, and they found that the denitrification process enhanced about 350% with the anoxic reactor.

Hiras, et al. (2004) tested two stages RBC system with anoxic and aerobic reactor (Figure 18), the anoxic unit consists of fully immersed biodisks, and the aerobic unit consists of RBC unit partially submerged, where the wastewater recycled up to four times to the anoxic reactor, the previous schematic illustrates the process.

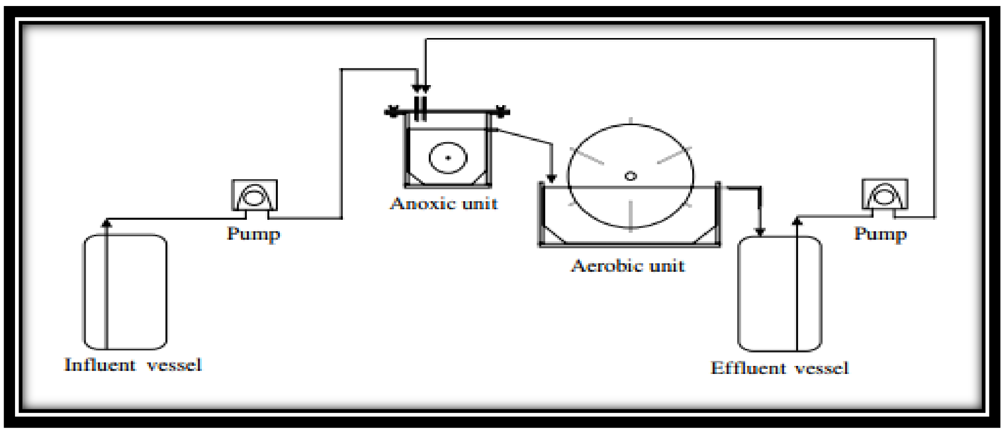

Figure 18: Schematic diagram for the RBC reactor.

They found that the BOD and TSS removal efficiency increased from 82% and 86% up to 94% and 97%, respectively, and the total nitrogen removal increased up to 3 times.

The treated wastewater in TRWWTP needs further treatment to reach the minimum requirements of the reuse in irrigation, as the total nitrogen should not be more than 50mg/l, so the suggested anoxic reactor will increase the costs of the investment costs by 350,000 NIS and the operation and maintenance costs by 0.1 NIS/m^3 (Alonso, et al., 2010).

4 CHAPTER FOUR

METHODOLOGY

This study compares various beneficial uses of reclaimed water considering treatment levels and location of reuse, by computing the costs and net benefits. The case studies relate to selective functional wastewater treatment plants; Al Taybeh & Rammun WWTP, Alteereh MBR and Anza WWTP. The technical concepts of wastewater characteristics, type of installed treatment technologies, and level of treatment will be described. The annual capital expenditures [CAPOX] and operational expenditures [OPEX], costs of health and environmental hazards and benefits will be estimated.

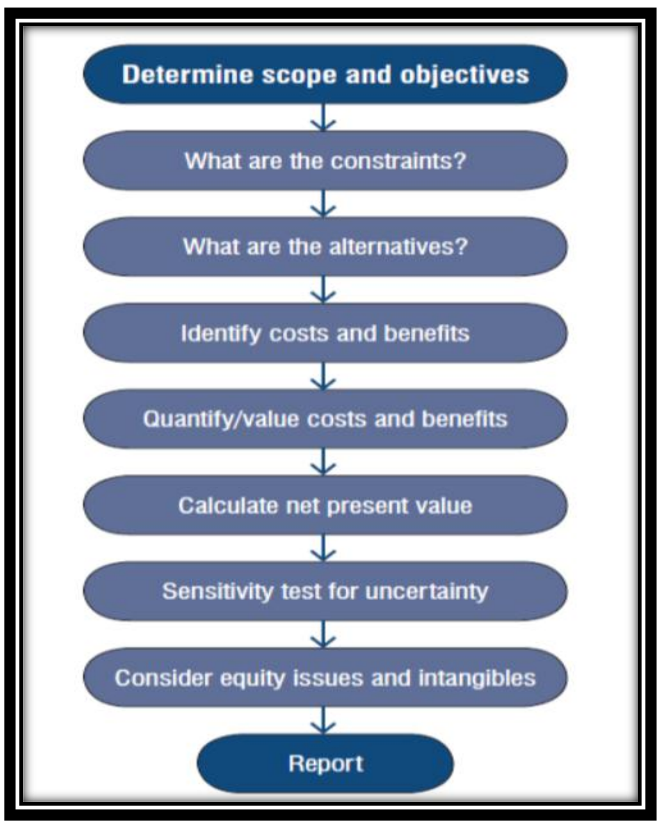

Figure 19: CBA steps (Commonwealth of Australia, 2006)

The cost/benefit analysis (CBA) will be applied as a tool to determine the costs and benefits of reclaimed water use in a systematic manner to identify and select the sustainable beneficial use for reclaimed water (Wikipedia, 2014). Since the 19th century, the CBA is widely used in appraising the environmental policies, taxes and projects. For example, France used CBA to appraise infrastructure projects, then it was used widely but in divergent ways and techniques until 1930 when USA used it into water-related investments. Till now the CBA is considered as the major appraisal technique involved in the environmental and social related projects, investments and policies (OECD, 2006) Estimating the CBA, the steps opted for are depicted in Fig. 19, and described below:

1. Determine Scope and Objectives

   The scope of work will be the three WWTPs effluent quality, quantity and availability which should be used in the most beneficial use as the reuse alternatives. The identification process should determine the costs and benefits involving the investment, and also should determine the alternatives of the investment (Greenberg, 1998; Lavee, 2011).

   The reuse alternatives should be determined and discussed, costs and benefits of reuse project then the net present value for the 20 years life cycle of the project will be calculated and finally the sensitivity analysis will be applied to measure the project reliability under the change of many variables as discount rate and reclaimed water price.

2. The constrains identification

   The constrains involved in the reclaimed water reuse will be studied and determined such as the effluent quality, quantity, the technical issues related to pumping or storing the reclaimed water, the social constrains, environmental constrains, legal and policy constrains and the political constrains. Non-market value for socio-political and environmental costs shall be estimated using an adapted model early applied for reclaimed water use in Israel (Haruvi, 1999; Lavee, 2013).

3. The alternatives identification

   The reuse alternatives are dependent on the effluent characteristics and will include the agricultural reuse, industrial reuse, and recreational reuse, artificial water recharge for groundwater and surface water and for landscape. The various use options will include discharge of reclaimed water into stream [water for nature and recreation], use in restricted and unrestricted irrigation. The selection for an intended use option is governed by the technology type producing certain effluent quality dictated by other factors like availability of agricultural land and willingness of farmers to accept and pay for the service provided (Al-Sa`ed, 2007; Abu Madi et al., 2008). Knowing the net benefit values for different use options will assist decision makers opt for the sustainable solution of reclaimed water use.

4. Cost and benefit identification

The costs and benefits involved in the reuse project will be discussed, as the costs related to the reuse project include (Kihila et al., 2014):

- Initial investment cost, including any additional treatment needed to reuse the reclaimed water, pumps, reservoirs and distribution networks.
- Operation and maintenance costs, for the pumps and the distribution network.
- Depreciation costs, as every item of the reuse project have service life and then should be replaced.

All the previous mentioned costs will be studied only for the reuse project and not for the WWTP, because all the costs related to the treatment plant will be paid by the people connected to the wastewater collection system under the rule of the "polluter pays principle", where the village council calculates the costs related to the treatment plant per m^3 of treated wastewater and adds it to the monthly water invoice.

The benefits related to the reuse project include (Molinos-Senante et al., 2011):

- Improved crop production due to the use of the reclaimed water.
- Nutrients provided by the reclaimed water which can reduce the fertilizers costs.

- Employments opportunities as the reuse project will need staff for operation and maintenance and the availability of reclaimed water to use in agriculture will push people to work more in their lands.

4.5 Costs and benefits quantification

All mentioned costs and benefits will be given a monetary value by using the actual existing data for the head cost, O&M costs, implementation of storing facilities , pumping stations and distribution networks. But for the social costs the questionnaire will be distributed so as to determine the WTP and WTA then the social costs can be evaluated, for the environmental costs the current and proposed damage and control costs will be studied and the environmental taxes can all evaluate the environmental costs.

The costs and benefits can be divided into two main categories, internal costs and benefits and external costs and benefits, these two categories will be studied and evaluated (Molinos-Senante et al., 2011):

1- Internal benefits: are the benefits related directly to the wastewater generation and reuse project as follows:

a- Revenues from the sale of the reclaimed wastewater directly to the beneficiaries, in Anza village the willingness to pay for the reclaimed wastewater was found to be 1.1NIS/m^3 (Arafat, 2012), the revenue from the sale of the reclaimed water B_1 is calculated by the following equation :

$$B1 = \sum_{n=0}^{n} \text{AVWn} \times \text{SPWn}$$

Equation 1

Where:

B_1 = benefits from the sale of reclaimed water to the farmers.

AVW_n= Average annual Volume of reclaimed Water (m^3/yr).

SPW_n = Selling Price of reclaimed Water (NIS/m^3).

The calculated benefits should be expressed as present value, so the discount rate should be applied for every year as follows:

Equation 2: $$\mathbf{B1_n} = \frac{\boldsymbol{AVWn \times SPWn}}{\boldsymbol{(1+d)^n}}$$

Where, d: is the discount rate 5%.

b- Revenues from the recovery of the nutrients, as the reclaimed water is used for agriculture, the nutrients which are found in the reclaimed water can supply the plants with the needed nutrients without the need of adding fertilizer, so every kg of Nitrogen (N) and phosphorus(P) is calculated from the effluent of the treatment plant, and is recovered as revenue as the following equation B_2 (Molinos-Senante et al., 2011):

Equation 3: $$\mathbf{B2} = \sum_{\boldsymbol{n=0}}^{\boldsymbol{n}} (\mathbf{ACPn} \times \mathbf{SPPn}) + (\mathbf{ACNn} * \mathbf{SPNn})$$

Where:

ACPn: is the Annual Volume of recovered Phosphorus (kg/yr).

SPPn: is the selling price of recovered phosphorus (NIS/kg).

ACNn: is the Annual Volume of recovered Nitrogen (kg/yr).

SPNn: is the selling price of recovered Nitrogen (NIS/kg).

Also, the previous equation should be expressed as present value, so the discount rate should be applied for every year as follows:

Equation 4: $$\mathbf{B2_n} = \frac{\boldsymbol{ACPn \times SPWn}}{\boldsymbol{(1+d)^n}} + \frac{\boldsymbol{ACNn \times SPNn}}{\boldsymbol{(1+d)^n}}$$

2- Internal costs: this item includes the investment costs and operation and maintenance costs:

a- Investment cost: including the pumps, reservoirs, pipes and fittings, civil and installation works and if there is any need to additional treatment process, every item should be calculated and then the depreciation rate for every type of the items is found so as to include it in the calculation, the following equations illustrates the calculated costs:

Equation 5: CI= $(\boldsymbol{Np} * \boldsymbol{Pp}) + (\boldsymbol{Ns} * \boldsymbol{ps}) + (\boldsymbol{Cf} * \boldsymbol{Pf}) + (\boldsymbol{Ct} * \boldsymbol{Pt})$

Where:

CI: Investment cost (NIS).

Np: number of pumps (units).

Pp: price of unit of pump (NIS/unit).

N_s: number of storage tanks (units)

P_s: price of storage unit (NIS/unit).

C_f: number of conveyance items.

P_f: Price of conveyance system.

C_t: Further treatment items.

P_t: Price of treatment items.

b- Depreciation cost: the monetary value of the reuse items decreases with time, due to wear or consuming, this cost can be calculated using the depreciation, every item have its own depreciation rate Table4-1 summarizes the depreciation rate for every item of the treated wastewater reuse:

Table 4-1: Depreciation rate for the treated wastewater reuse items. (AZCC, 2003)

Depreciable Plant	Average Service Life (Years)	Annual Accrual Rate (%)
Reuse Services	50	2.00%
Reuse Distribution Reservoirs	40	2.50%
Reuse Transmission and Distribution System	40	2.50%
Pumping Equipment	8	12.50%

Equation 6: $\mathbf{Dc= \frac{1}{n}\times CI}$ **(AZCC, 2003)**

Where:

Dc: is the Depreciation costs (NIS).

N: average service life (years).

CI: investment cost of item (NIS).

c- Operation and Maintenance (O&M) costs: including the power consumption as electricity for operating the pumps, staff for operation and maintenance, administration costs for the meters reading and connections licensing, as the wastewater is treated regardless of the reuse of the reclaimed water, then the costs will exclude the treatment process costs, and costs will include the reuse facilities operation and maintenance costs (pumping, storage and distribution), so the operation and maintenance costs were found to be (0.04 $\$/m^3$) (RAND, 2007).

The electricity consumption for the pumps is estimated by the following equation (Vogelesang, 2008):

Equation 7: $$\mathbf{P_{electic} = \frac{Q \times \Delta P}{3.6 \times \eta p}}$$

Where:

$P_{electric}$: Electrical power consumption (KWh).

Q: Water pumped (m^3/hr).

ΔP : Head difference (bar).

ηp : Pump efficiency (0.75 for centrifugal pumps) (Neutrium, 2012).

For the staff of operation and maintenance usually for small scale water reuse project one person is adequate (Jagals, et al., 2008), if the average daily salary for the worker in Palestine is 16.7$ (PCBS, 2014) then the average monthly salary for one worker is 500$.

So the total operation and maintenance costs equation will be:

Equation 8: $$\mathbf{OMC = P_{electric} + Staff\ salary}$$

3- External benefits: every benefit results from the reusing of reclaimed water is considered as external benefits:

a- Marginal benefits resulted from irrigating the crops with reclaimed water: there are two ways to quantify the benefits on the crops resulting from using reclaimed water, the first way is estimating the quantity of fresh water used usually to irrigate the crops before the reuse project, then multiply by the fresh water price to get the previous costs paid by the farmers, then the previous costs subtracted from the cost of the reclaimed water to get the marginal benefits as the fresh water price is always more expensive than the reclaimed water, the following equation illustrates the marginal benefits:

Equation 9: $$\mathbf{B_m = (Qf \times Pf)-(Qr \times Pr)}$$

Where: B_m : Marginal benefit from reuse (NIS).

Q_f : Quantity of Fresh water for used for irrigation(m^3).

P_f: Price of fresh water (NIS/m^3).

Q_r : Quantity of reclaimed water reused (m^3).

P_r : Price of reclaimed water (NIS/m^3).

The second method is to estimate the area of the agricultural lands in the reuse project, then determine the type of crops can be cultivated in the lands and the existing crops, then calculate the needed quantities for irrigation for these lands, and find the benefits from cultivate and irrigate these lands with the specified crops.

The disadvantage of the first method is that it gives narrow estimation about the real benefits of the reuse of reclaimed water, as it compares the water quantities and not the crops types and real values.

The disadvantage of the second method is that it needs a lot of research, surveys and experts in many fields, which adds high cost for the research.

- Employment opportunities, the availability of the reclaimed water for irrigation can create good opportunities for the farmers to work full time with their relatives in their agriculture land; it was found that 85.2% of households have the willingness to work in their land after the implementation of the reuse of reclaimed water project (Arafat, 2012).

  The employment have social and economic benefits, as it creates opportunities for production and raise the peoples income, and it can reduce the unemployment in the society (Hussein, et al., 2002).

  The employment benefits will be estimated relying on the fact that 85.2% of the households have the will to work in their lands if water is available for irrigation, and the total number of population multiplied by the unemployment rate in Palestine taken from the PCBS which is 16.3% in West Bank (PCBS, 2015), then the equation used to estimate the employment benefit is:

Equation 10: $\boldsymbol{Be = P \times W\% \times U\% \times Savg}$

Where: B_e: Employment benefits (NIS).

P: population (PE).

W%: Households willing to work in agriculture after the reclaimed water project (85.2%)

U%: Unemployment rate in Palestine (16.3%).

S_{avg}: The annual income from land per farmer (2034NIS/year) (Arafat, 2012).

- Environmental benefits, as the discharge of the treated effluent into the streams have adverse effects on the environment (groundwater pollution), and can cause water borne diseases as the mosquitoes breed in the streams then transmit the diseases to people, or by direct contact between the people and the wastewater in the stream. The waterborne diseases found to be 33% of the total diseases in the rural areas in Palestine (Alkhatib, et al., 2010). This causes many social and economic costs due to clinical expenses and in some cases the patient could take medical vacation for many days, while these diseases rarely cause death for children in Palestine on the other hand their parents should devote time for caring about their ill children which causes economic and social stress (UNC, 2013)

- Preventing the Occupation government from deducting money from the Palestinians collected customs and taxes for the cost of treatment plants inside the green line, as it considered it as transboundary wastewater and after the treatment the Israeli government sells the reclaimed water for the users without returning the benefits to the Palestinian. More than 34 million$ were deducted from the Palestinians money during the period (1994-2008) (Alsa`ed, et al., 2010), but in our case the three WWTPs under study have low flow which will not flow throw the stream to Israel.

b- External costs: the health risks when using the reclaimed water is considered as the main external cost in our reuse projects. In Greece, the sewage workers and control workers in wastewater treatment plants were checked for the presence of antibodies against hepatitis A (HAV) and hepatitis B (HBV) viruses. Results showed that 65.7% of sewage workers had antibodies for HAV. While, 32.6% of control people had them, this means that, they were exposed to the risk of HAV. Besides, they found that 32.4% of sewage workers and 5.8% of control people had antibodies against HBV. This indicates that they were also exposed for the risk of HBV. As a result of this they assured the importance of the immunization against these diseases by vaccinations (Arvanitidou, et al., 2004). In addition, the National Institute for Occupational Safety and Health (NIOSH) recommended that the workers in wastewater should be immunized against tetanus-diphtheria by vaccinations (DEP, 2002). The diphtheria, HAV and HBV vaccination preferable to be taken once every ten years (Vaccines, 2015). The vaccinations prices for the adults are 5.37$ for (HAV& HBV) and 1.23$ for diphtheria vaccinations (CDC, 2016).

The external costs will be calculated by multiplying the costs of vaccinations by the number of the farmers willing to use the reclaimed water, so as to immunizing them against any health risks.

Net Present Value (NPV) Calculation for Costs and Benefits

The NPV presents the time value of the money, and it equals the present value of all benefits minus the present value of all costs, so how much the NPV was higher the investment will be more recommended due to the high return and benefits (BeatrizdeBlas, 2006).

Equation 11: $\mathbf{NPV(r) = SUM\,[t, (B_t - C_t)\,(1+r)^{-t}}$ **(Abumadi, 2005)**

Where: t: is the number of years.

$B_t - C_t$: are the benefits minus the costs at specific year t.

r: is the discount rate also called (d).

also the benefits to costs ratio (B/C) is calculated using the following equation:

Equation 12: $\mathbf{BC_{ratio} = SUM[\,t, B_t(1+r)^{-t}]/SUM[t,\ C_t(1+r)^{-t}]}$ **(Abumadi, 2005)**

This is an indicator for the benefits to cost return, as if B/C ratio is more than 1 then the project can be accepted and the higher value means higher return, but if the B/C ratio is less than 1 then the project is not justified.

Sensitivity Analysis

The sensitivity analysis (SA) is determines how the uncertainty in the outputs affected by the uncertainty in the inputs (Saltelli, 2002).In a study on reclaimed water reuse, the SA will determine the input costs and benefits that will affect the output values, so the decision maker knows the uncertainties involved in the investment to reduce its effects.

Discount rate

As Palestine doesn't have specified discount rate in the field of water reuse projects, then the average discount rate for Israel and Jordan is taken as 5% (Nazer, 2010).

Project study horizon

The project study period for the use of the NPV calculation is 10 years.

5 CHAPTER FIVE

RESULTS & DISCUSSION

After the previous illustrated CBA methodology was applied the following results were obtained for every reclaimed wastewater reuse project for 10 years as period of analysis and 2.6% as the rate of population growth in Palestine (PCBS, 2015):

5.1 Anza Reclaimed Water Reuse Project:

5.1.1 Determine scope and objectives:

The reuse project in Anza village is limited to agricultural reuse, due to the fact that the site of the WWTP is near the agricultural lands. The inhabitants of Anza village are mainly farmers who are willing to work in their lands and 94.6% of the farmers are willing to use the reclaimed water from the WWTP (Arafat, 2012). Because there are no industrial activities in the village, the agricultural project will be the only alternative for this study.

5.1.2 The constrains identification

The WWTP was constructed with complete reuse project, including the reclaimed water pumps, main transmission lines, reservoirs, distribution pipes and farm connections, under the project of " *Beit Dajan & Anza villages produce more food through sustainable and safe use of reclaimed wastewater in agriculture*" funded by the EU and implemented by PARC (Al Sa`ed, 2015). The only constrains was to raise the knowledge and acceptance of farmers to use the reclaimed water in their agricultural activities, which was achieved by many public hearings and lecture sessions about the project (Arafat, 2012). The availability of the reclaimed water during the summer season is considered as a limiting constrain as mainly the olives and almonds need to be irrigated during the period from April to September, so just limited number of dunums can be irrigated during the year.

5.1.3 The alternatives identification

Anza WWTP produce reclaimed water with good quality (30, 30, 50) BOD, TSS and TN, respectively, which is in accordance with the Palestinian agricultural reuse standards. So the reclaimed water reuse in agricultural will be the first alternative, the second alternative which will be studied, is the discharge of the reclaimed water into the stream which economically equals to no project, the costs and benefits for every alternative will be discussed and the net present value will show the most effective alternative should be used.

5.1.4 Cost and benefit quantification

The costs and benefits for the reuse project were calculated as follows:

1- Internal Benefits:

- the benefits from selling the treated effluent from the wastewater treatment plant, where not all the reclaimed water will be utilized by the farmers, the number of available dunums to be irrigated will be estimated, and the needed quantities of reclaimed water will be calculated compared to the available treated water and the irrigated lands.

  The expected reclaimed water generated is calculated using the exponential growth equation as follows:

Equation 13: $\mathbf{Qn = Q_0 \times e^{n*r}}$

Where:

Qn: The Expected Quantity of treated water at year n (m^3/yr).

Q_0: The Quantity of Treated water at year 0 (m^3/yr).

n: Number of Years.

r: natural population growth rate 2.6%/yr.

Data taken from the local village council about the available lands to be irrigated and the crops cultivated in these lands, these data were used to estimate the expected reclaimed to be used in irrigation yearly, Figure 20 used to determine the quantities of reclaimed water to be used as an example for the year 2025.

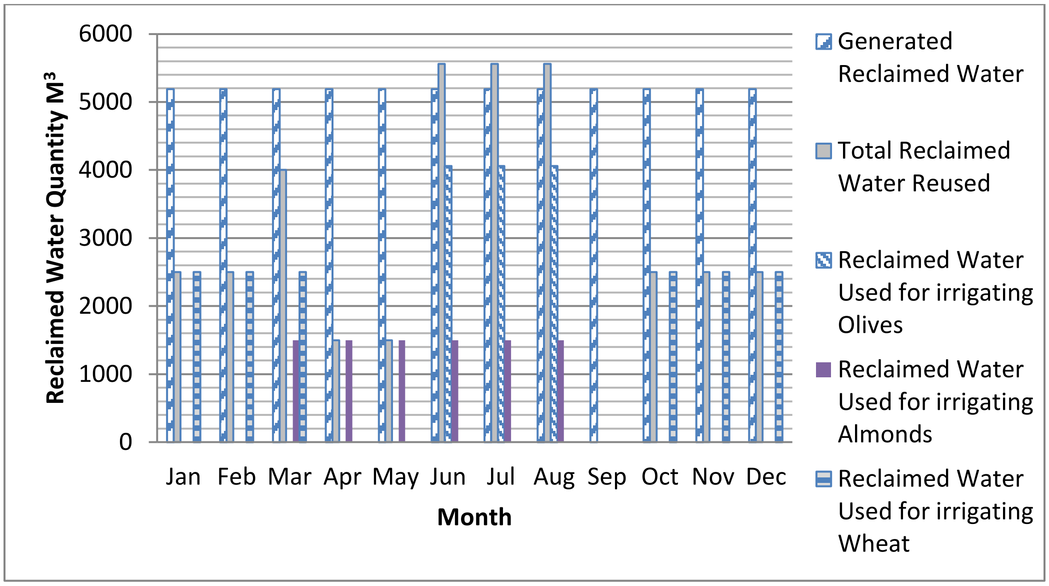

Figure 20: Expected Reclaimed Water Reused in Anza during the year 2025

The expected reclaimed water produced and used are estimated yearly and illustrated in Figure 21.

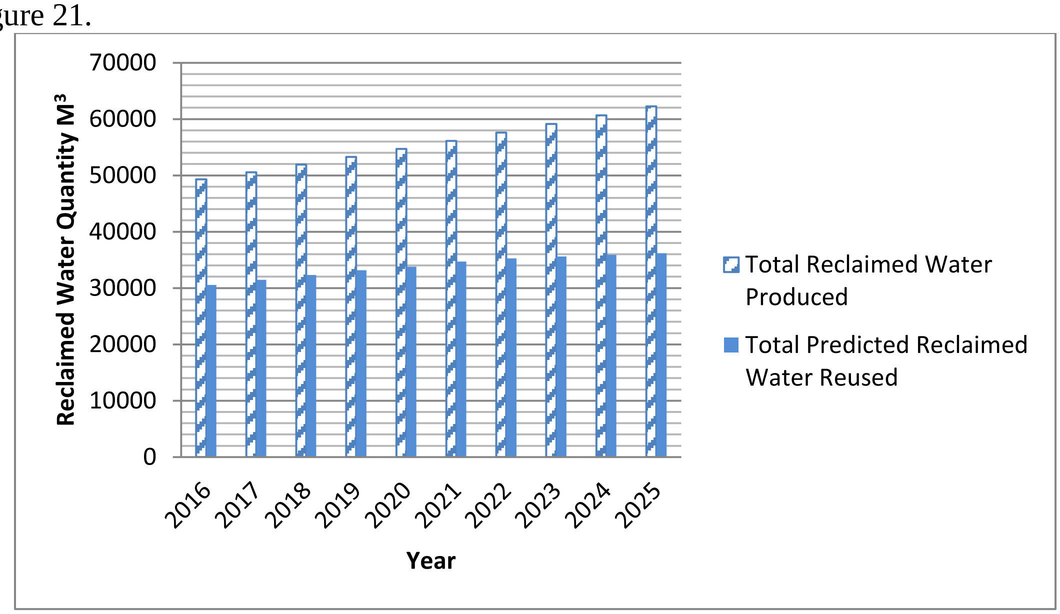

Figure 21: Expected Reclaimed Water Generated and Reused Yearly (m^3/yr).

The benefits from selling the reclaimed water to the farmers are calculated upon the reclaimed water tariff of 1 NIS/m^3. Table 5-1 shows the calculated benefits yearly.

Table 5-1: The benefits from selling the reclaimed water for farmers in Anza.

No.	0	1	2	3	4	5	6	7	8	9
Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Treated water (m^3/y)	49275	50573	51905	53272	54676	56116	57594	59111	60668	62266
Reclaimed water sold(m^3/y)	30570	31440	32310	33180	33780	34680	35280	35580	35880	36180
Reclaimed water price(NIS)	1	1	1	1	1	1	1	1	1	1
Benefits from reclaimed water sold(NIS)	30570	31440	32310	33180	33780	34680	35280	35580	35880	36180

1- Internal costs: investment costs and operation and maintenance costs for the reuse projects.

- Investment cost: including the pumps, reservoirs, pipes and fittings, civil and installation works and if there is any need to additional treatment process, the following equation used for the calculation of the investment cost.

Equation 14: CI= $(\boldsymbol{Np} * \boldsymbol{Pp}) + (\boldsymbol{Ns} * \boldsymbol{ps}) + (\boldsymbol{Cf} * \boldsymbol{Pf}) + (\boldsymbol{Ct} * \boldsymbol{Pt})$

Dc= $\frac{1}{n} \times$ CI

As the reuse project is implemented by PARC, so the investment cost is known and there is no need to calculate it but the data taken from PARC can be used to calculate for other reuse projects, also the depreciation costs were calculated for every item, tables (5-2) to (5-8) illustrate the items of the reuse project with its related costs:

- Conveyance system: which include the pipes, fittings and installations of the reuse network; also the depreciation costs were calculated based on the data taken from table (5-2) where the conveyance system average service life is taken to be 40 years. Table5-2 illustrates the costs of the reuse network.

Table 5-2: Conveyance system costs

Item	Unit	Quantity	Price of unit (NIS)	total (NIS)
PE 4"	3500	m	27	94500
PE 2"	4500	m	6.75	30375
PE 32mm	16500	m	2.7	44550
PE 16mm	7000	m	1.35	9450
Fittings and installation	LS	NA	NA	85500
Total Fittings Costs (NIS)				264375

The depreciation rate for the coveyance system is 2.5% per year. Table5-3 illustrates the depreciation costs for the coveyance system.

Table 5-3: Depreciation costs for the coveyance system

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment cost (NIS)	264375	0	0	0	0	0	0	0	0	0
Depreciation rate	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Depreciation cost(NIS)	6609	6609	6609	6609	6609	6609	6609	6609	6609	6609

- Storage : including one 500 m^3 metallic storage tank used for the storage of treated wastewater, then the treated wastewater flows by gravity to the farmers, the depreciation cost calculated as the average service life of 40 years, the investment cost for the tank is 100,000(NIS) with depreciation rate of 2.5% per year. Table 5-4 illustrates the costs related to storage:

Table 5-4: Costs of Storage system at Anza reuse project.

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment cost (NIS)	100000	0	0	0	0	0	0	0	0	0
Depreciation rate	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Depreciation cost(NIS)	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500

- Pumps: one centrifugal pump is used to lift the treated wastewater from the treatment plant to the storage tank, with head of 65m and 22 m^3/hr., the investment cost of the pumps is 20,000 (NIS), and the average service life of it is 8 years with depreciation rate of 12.5% per year. Table5-5 illustrates the costs related to the pumps.

Table 5-5 : Costs of pumping system at Anza reuse project.

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment cost (NIS)	20000	0	0	0	0	0	0	0	0	0
Depreciation rate	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Depreciation cost(NIS)	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500

- Operation and maintenance costs: the operation and maintenance of the reuse system can be done by one employee, also the needed parts cost for the maintenance can be recovered from the users, so the employee has a monthly salary of 2,200 (NIS) with an annual increase rate of 2.5%. Table05-6 illustrates the calculated costs related to the operation and maintenance of reuse scheme.

Table 5-6: O&M costs for Anza reuse project

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Increase rate of salary	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Total yearly salary costs (NIS)	26400	27060	27737	28430	29141	29869	30616	31381	32166	32970

- The electricity costs for the operation of the pump is calculated to be 0.2(NIS/m^3), so the electricity costs of pump is calculated as illustrated in Table5-7.

Table 5-7: Costs of electricity for pumps used in Anza reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Reclaimed water Pumped (m3/y)	30570	31440	32310	33180	33780	34680	35280	35580	35880	36180
Electricity cost (NIS/m3)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Electricity costs(NIS/yr)	6114	6288	6462	6636	6756	6936	7056	7116	7176	7236

The total internal costs are illustrated in Table5-8.

Table 5-8: Total internal costs for Anza reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total internal costs yearly (NIS)	428498	44957	45808	46675	47506	48415	49281	50107	50951	51815

After comparing the Total internal costs and benefits we found that the reuse project will not be feasible, as the costs are very high compared to the benefits. Table5-9 illustrates the costs- benefits difference.

Table 5-9: CBA for Internal items of the reuse project in Anza.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Cost-Benefits for Internal items (NIS)	-397928	-13517	-13498	-13495	-13726	-13735	-14001	-14527	-15071	-15635

The costs benefits analysis for the project should take into consideration that the government should participate in the reuse project costs, and the difference should be paid by the local village council so as to operate the reuse project in sustainable manner.

As shown in the first year where the costs-benefits difference is very high due to the investment costs, usually the reuse project is implemented by donors, and the investment costs can be neglected.

2- External benefits: as illustrated in the methodology, the external benefits including the marginal benefits from irrigating the crops which is usually been rain fed, the nutrient recovery from the reclaimed water as fertilizer, and the employment opportunities which created by the availability of the water to work in the agricultural lands.

- Marginal benefits from irrigating the crops: most the agricultural lands in served in treated water reuse project in Anza village are cultivated in olives, orchards and wheat, all these crops are rainfed, but when the crops are irrigated with reclaimed water the crop production will improve and also the benefits will increase, the marginal benefits are calculated by estimating the area cultivated in the crop and then multiplying it by the difference between the benefits from the crops which are rainfed and the benefits from irrigating the crops, in Anza village the estimated agricultural area served by the reuse project and is cultivated with olives, orchards and wheat are (350,50,100)dunums respectively. Table5-10 illustrates the benefits per dunum for every crop with and without the reuse project:

Table 5-10: Marginal benefits per dunum from the reuse project (GFA, 2015, Mizyed, 2013).

Crop	olives		Almonds		Wheat	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Net benefits (NIS/dunum)	708	1,965	3,382	6,539	453	830
Marginal benefits (NIS/dunum)	1,257		3,157		377	

The marginal benefits from irrigating the olive trees are illustrated in Table5-11.

Table 5-11: Marginal benefits from irrigating olives in Anza.

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Marginal benefits from irrigating olives (NIS/dunum.year)	1,257	1,257	1,257	1,257	1,257	1,257	1,257	1,257	1,257	1,257
Number of dunums of olive	55	60	65	70	70	70	70	70	70	70
Benefits from irrigating olives (NIS)	69135	75420	81705	87990	87990	87990	87990	87990	87990	87990

The marginal benefit from irrigating the almonds trees is illustrated in the Table5-12.

Table 5-12: Marginal benefits from irrigating Almonds in Anza.

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Marginal benefits from irrigating Almonds (NIS/dunum.year)	3,157	3,157	3,157	3,157	3,157	3,157	3,157	3,157	3,157	3,157
Number of dunums of Almonds	20	20	20	20	22	25	27	28	29	50
Benefits from irrigating Almonds (NIS)	63140	63140	63140	63140	69454	78925	85239	88396	91553	157850

The marginal benefit from irrigating the wheat cereals is illustrated in Table5-13, where the available land is about 100 dunum at the plain area.

Table 5-13: Marginal benefits from irrigating Wheat in Anza.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Marginal benefits from irrigating Wheat (NIS/dunum. year)	377	377	377	377	377	377	377	377	377	377
Number of dunums of Wheat	100	100	100	100	100	100	100	100	100	100
Benefits from irrigating Wheat (NIS)	37700	37700	37700	37700	37700	37700	37700	37700	37700	37700

- Benefits from the nutrients recovery for both nitrogen and phosphorus, where the recovered nitrogen was calculated based on its concentration in the effluent (40 mg/l), and (3 mg/l) for the phosphorus, where market prices of (7.6, 8 NIS/kg) respectively for the fertilizers included the nitrogen and phosphorus, these benefits considered as environmental benefits. the following equation was used to calculate benefits:

$$\textbf{Equation 15: } \mathbf{B2} = \sum_{n=0}^{n} (\mathbf{ACPn} \times \mathbf{SPPn}) + (\mathbf{ACNn} * \mathbf{SPNn})$$

The calculated benefits from the nutrients recovery is in Tables (5-14 &5-15).

Table 5-14: Expected benefits from nitrogen recovery as fertilizer.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Reclaimed water Used(m^3/y)	30570	31440	32310	33180	33780	34680	35280	35580	35880	36180
Nitrogen concentration in effluent(kg/m^3)	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Recovered Nitrogen(kg/y)	1223	1258	1292	1327	1351	1387	1411	1423	1435	1447
Price of the Nitrogen(NIS/kg)	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
Benefit from the recovered nitrogen(NIS/y)	9293	9558	9822	10087	10269	10543	10725	10816	10908	10999

Table 5-15: Expected Benefits from Phosphorus recovery as fertilizer.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Reclaimed water sold(m^3/y)	30570	31440	32310	33180	33780	34680	35280	35580	35880	36180
Phosphorus concentration in effluent(kg/m^3)	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Recovered Phosphorus(kg/y)	92	94	97	100	101	104	106	107	108	109
price of the Phosphorus(NIS/kg)	8	8	8	8	8	8	8	8	8	8
Benefit from the recovered Phosphorus(NIS/y)	734	755	775	796	811	832	847	854	861	868

- The benefits from the employment were included in the costs and benefits of the irrigation of the lands, many items including the costs of the workers in the lands were taken into consideration in the marginal benefits calculations.

The total external benefits are summed and illustrated in Table5-16.

Table 5-16: Total external benefits from the reuse project in Anza.

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total benefits (NIS)	180002	186572	193143	199713	206224	215990	222501	225756	229012	295407

- External costs: as illustrated in the methodology, the health risks and costs is the main item in the costs, the vaccinations costs are calculated as illustrated in Table5-17.

Table 5-17: Costs of vaccinations for the farmers in Anza reuse project

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
No. of farmers	321	338	347	356	365	375	385	395	405	416
No. of farmers to take vacciations	321	17	9	9	9	10	10	10	10	11
price of diptheria vaccinations (NIS)	5	5	5	5	5	5	5	5	5	5
price of HAV & HBV vaccinations (NIS)	22	22	22	22	22	22	22	22	22	22
Total costs (NIS)	8481	449	238	238	238	264.2	264	264.2	264.2	290.6

The costs to benefits difference for the external items are illustrated in Table5-18.

Table 5-18: Costs- Benefits for the external items of the reuse project in Anza

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Costs- Benefits for the external items (NIS)	171521	186123	192905	199475	205986	215726	222237	225492	228747	295116

From Table5-18 we can conclude that the external benefits exceeds the external costs, so the social and environmental benefits are higher than the costs, which will have very positive effects on the people and farmers.

- The net present value: the net present values for the costs and benefits are calculated and illustrated in Table5-19.

Table 5-19: NPV for Anza reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total internal costs (NIS)	-428498	-44957	-45808	-46675	-47506	-48415	-49281	-50107	-50951	-51815
Total internal benefits (NIS)	30570	31440	32310	33180	33780	34680	35280	35580	35880	36180
Total external costs (NIS)	-8481	-449	-238	-238	-238	-264	-264	-264	-264	-291
Total external Benefits (NIS)	180002	186572	193143	199713	206224	215990	222501	225756	229012	295407
Cashflow	-226407	172606	179407	185980	192260	201991	208235	210965	213676	279481
NPV (NIS)	**1150380**									

- From the previous table the NPV for Anza reclaimed water reuse project is **1,150,380** (NIS), which is positive value and implies that the reuse project is justified to be implemented.

The Benefit to Cost Ratio (B/C) is calculated for Anza reuse project and illustrated in Table5-20.

Table 5-20: B/C ratio for Anza Reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total Costs	-436979	-45407	-46046	-46913	-47744	-48679	-49545	-50371	-51215	-52106
Total Benefits	210572	218012	225453	232893	240004	250670	257781	261336	264892	331587
Costs NPV	-743767									
Benefits NPV	1894148									
B/C	**2.55**									

It can be noted that the B/C ratio is 2.55, which indicates that the reuse project in Anza can get benefits more than double of the costs involved in the projects which means that the project is justified.

5.2 Al Taybeh and Rammun Reclaimed Water Reuse project:

5.2.1 Determine scope and objectives:

The reuse of reclaimed water project aimed at raise the productivity of the rainfed lands in Al Taybeh and Rammun towns to produce more food, increase the farmer's income and the reclamation of the agricultural lands in both towns.

5.2.2 the constrains identification

As illustrated in the previous sections the TRWWTP produce treated water with quality of (35, 60, 114) as BOD, TSS and TN (mg/l); respectively, this quality does not match the PSI for the use of the reclaimed water in irrigation, so further treatment should be done for the reclaimed water before reuse to reduce the TN below 50mg/l, the additional treatment costs will be added to the studied reuse project, after these additional treatment the treated water can be used in restricted irrigation.

5.2.3 The alternatives identification

There are two main alternatives for the reuse project, the first one is to invest in tertiary treatment for the effluent so as to reuse it in the restricted irrigation for the trees and the cereals, and the second alternative is to reuse the treated effluent in the concrete mixing factory near the TRWWTP.

The previous mentioned options will be studied and the NPV will be calculated to determine which project is more justified.

5.2.4 Cost and benefit identification

There are different costs and benefits for the two alternatives, for the first option as the restricted irrigation:

- Investment costs for the tertiary treatment.
- Investment costs for the reuse project.

- Operation and maintenance costs, for the pumps and the distribution network.
- Depreciation costs, as every item of the reuse project have service life and then should be replaced.

The benefits from the irrigation project are:

- Improved crop production due to the use of the reclaimed water.
- Nutrients provided by the reclaimed water which can reduce the fertilizers costs.
- Employments opportunities as the reuse project will need staff for operation and maintenance and the availability of reclaimed water to use in agriculture will push people to work more in their lands.

5.5.5 Cost and benefit quantification

GFA, 2015 studied the reuse project in AlTaybeh and Rammun towns, they found that about 75% of reclaimed water can be used in irrigation if good water managemnt was done, the average pumping costs for both storage reservoiurs is 0.35 NIS/m^3, they also found that most of the agricultural lands are mainly planted with olives in both towns but in the Wadi Abul Hayyat area about 50 dunum is planted with cereals, in AlTaybeh and Rammun there is about 350 dunum which can be served by the reuse project and is planted with olives, orchards and cereals. Data about the costs and revenues from planting every type of plants were taken from the GFA study which was estimated based on water service fees of 1 NIS/m^3 of reclaimed water.

The costs and benefits for the reuse project were calculated as follows:

1- Internal Benefits:

- the benefits from selling the treated effluent from the wastewater treatment plant, where not all the reclaimed water will be utilized by the farmers, the number of available dunums to be irrigated will be estimated, and the needed quantities of reclaimed water will be calculated compared to the available treated water and the irrigated lands.

The expected reclaimed water generated is calculated using the exponential growth equation as follows:

Equation 16: $$Qn = Q_0 \times e^{n*r}$$

Where:

Qn : The Expected Quantity of treated water at year n (m^3/yr).

Q_0 : The Quantity of Treated water at year 0 (m^3/yr).

n : Number of Years.

r : natural population growth rate 2.6%/yr.

Data taken from the local village council about the available lands to be irrigated and the crops cultivated in these lands, these data were used to estimate the expected reclaimed to be used in irrigation yearly. Figure 22 used to determine the quantities of reclaimed water to be used as an example for the year 2025.

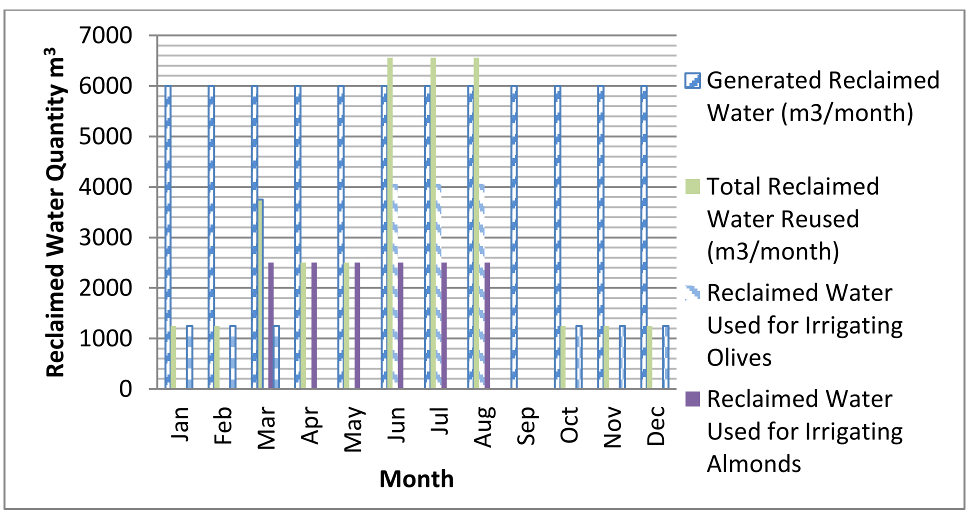

Figure 22: Expected reclaimed water reused in Taybeh & Rammun (year 2025).

The Expected quantities of reclaimed water generated and the expected reclaimed water to be reused results are illustrated in Figure 23:

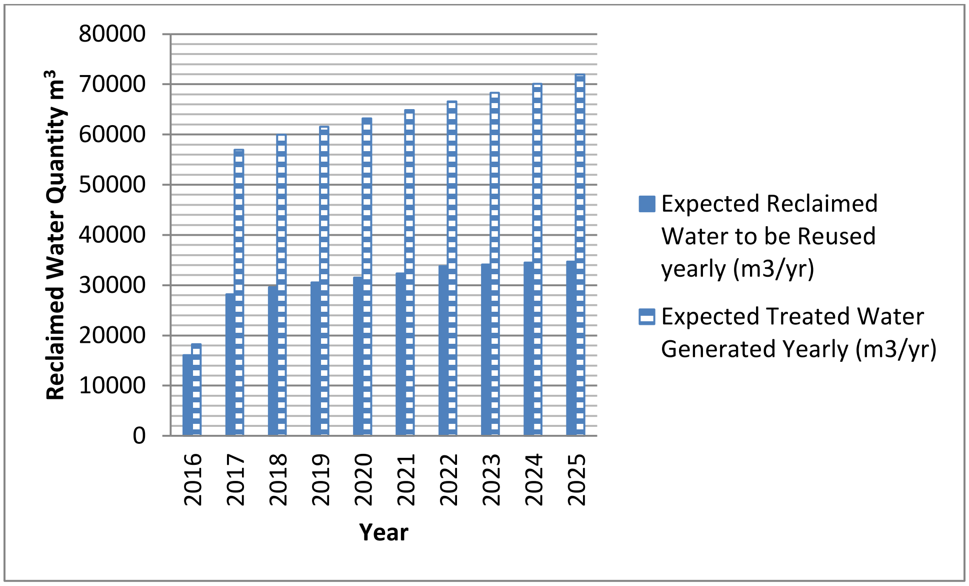

Figure 23 :Expected annual water generated and reused (m^3) in Taybeh & Rammun.

The benefits from selling the reclaimed water to the farmers are calculated upon the reclaimed water tariff of 1 NIS/m^3. Table5-21 shows the calculated benefits yearly.

Table 5-21: The benefits from selling the Reclaimed Water for Farmers in Taybeh & Rammun.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Treated water Generated (m^3/y)	18250	56940	59979	61559	63181	64845	66553	68306	70105	71952
Reclaimed water sold(m^3/y)	16110	28200	29622	30570	31518	32340	33810	34158	34506	34680
Reclaimed water price(NIS)	1	1	1	1	1	1	1	1	1	1
Benefits from reclaimed water sold(NIS)	16110	28200	29622	30570	31518	32340	33810	34158	34506	34680

3- Internal costs: investment costs and operation and maintenance costs for the reuse projects.

- Investment cost: : including the pumps, reservoirs, pipes and fittings, civil and installation works and if there is any need to additional treatment process, the following equation used for the calculation of the investment cost.

Equation 17: CI= $(\boldsymbol{Np} * \boldsymbol{Pp}) + (\boldsymbol{Ns} * \boldsymbol{ps}) + (\boldsymbol{Cf} * \boldsymbol{Pf}) + (\boldsymbol{Ct} * \boldsymbol{Pt})$

Dc= $\frac{1}{n}\times$ CI

Tables from (5-22) to (5-28) illustrate the items of the reuse project with its related costs:

- Conveyance system: which include the pipes, fittings and installations of the reuse network, also the depreciation costs were calculated based on the data taken from table (5-2) where the conveyance system average service life is 40 years. Table5-22 illustrates the costs of the reuse network.

Table 5-22: Conveyance system costs

Item	Quantity	Unit	price of unit (NIS)	Total (NIS)
PE 4"	3200	m	27	86400
PE 2"	5000	m	6.75	33750
PE 32mm	15000	m	2.7	40500
PE 16mm	6500	m	1.35	8775
Fittings and installation	LS	NA	NA	78750
Total Fittings Costs				248175

The depreciation rate for the coveyance system is 2.5% per year. Table5-23 illustrates the depreciation costs for the coveyance system.

Table 5-23: Depreciation costs for the coveyance system in Taybeh & Rammun.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment cost (NIS)	248175	0	0	0	0	0	0	0	0	0
Depreciation rate	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Depreciation cost(NIS)	6204	6204	6204	6204	6204	6204	6204	6204	6204	6204

- Storage : including two 500 m^3 metallic storage tank used for the storage of treated wastewater in both towns, then the treated wastewater flows by gravity to the farmers, the depreciation cost calculated as the average service life of 40 years, the investment cost for both tanks is 200,000(NIS) with depreciation rate of 2.5% per year. Table5-24 illustrates the costs related to storage:

Table 5-24: Costs of storage system at Taybeh & Rammun reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment cost (NIS)	200000	0	0	0	0	0	0	0	0	0
Depreciation rate	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Depreciation cost(NIS)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000

- Pumps: Two centrifugal pumps are used to lift the treated wastewater from the treatment plant to the storage tanks, the investment cost of the pumps is 40,000 (NIS), and the average service life of it is 8 years with depreciation rate of 12.5% per year. Table5-25 illustrates the costs related to the pumps.

Table 5-25: Costs of pumping system at Taybeh & Rammun reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment cost (NIS)	40000	0	0	0	0	0	0	0	0	0
Depreciation rate	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Depreciation cost(NIS)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000

- Operation and maintenance costs: the operation and maintenance of the reuse system can be done by one employee, also the needed parts cost for the maintenance can be recovered from the users, so the employee has a monthly salary of 2,200 (NIS) with an annual increase rate of 2.5%. Table5-26 illustrates the calculated costs related to the operation and maintenance of reuse scheme.

Table 5-26: O&M costs for Taybeh & Rammun reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Increase rate of salary	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Total yearly salary costs (NIS)	26400	27060	27737	28430	29141	29869	30616	31381	32166	32970

The electricity costs for the operation of the pumps are calculated to be with average value of 0.45(NIS/m^3), because the two storage tanks are in two different elevations, so the electricity costs of pumps are calculated as illustrated in Table5-27.

Table 5-27: Costs of electricity for pumps used in Taybeh & Rammun reuse project

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Reclaimed water Pumped (m3/y)	16110	28200	29622	30570	31518	32340	33810	34158	34506	34680
Electricity cost (NIS/m3)	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Electricity costs(NIS)	7250	12690	13330	13757	14183	14553	15215	15371	15528	15606

- Tertiary treatment costs: as illustrated in the study area of the TRWWTP, the effluent of the TRWWTP is not matching the PSI for reuse in irrigation due to the high nitrogen contents in the effluent, referring to the literature we found that the RBC WWTP usually do not achieve denitrification due to the high DO in the RBC units, so anoxic reactor should be added to the WWTP so as to reduce the nitrogen to an acceptable value for irrigation, this technology will increase the investment cost with 350,000 NIS. Table5-28 illustrates the additional treatment costs.

Table 5-28: Additional treatment costs for Taybeh & Rammun reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment cost (NIS)	350000	0	0	0	0	0	0	0	0	0
Depreciation rate	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Depreciation cost (NIS)	8750	8750	8750	8750	8750	8750	8750	8750	8750	8750

The total internal costs are illustrated in Table5-29.

Table 5-29: Total internal costs for Taybeh and Rammun reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total internal costs yearly (NIS)	896779	64704	66021	67141	68278	69377	70785	71707	72648	73530

After comparing the total internal costs and benefits we found that the reuse project will not feasible, as the costs are very high compared to the benefits. Table5-30 illustrates the costs- benefits difference for internal items.

Table 5-30: CBA for Internal items of the reuse project in Taybeh & Rammun

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
CBA for internal items (NIS)	-880669	-36504	-36399	-36571	-36760	-37037	-36975	-37549	-38142	-38850

The costs benefits analysis for the project should take into consideration that the government should participate in the reuse project costs, and the difference should be paid by the local village council so as to operate the reuse project in sustainable manner.

As shown in the first year where the costs-benefits difference is very high due to the investment costs, usually the reuse project is implemented by donors, and the investment costs can be neglected.

4- External benefits: as illustrated in the methodology, the external benefits including the marginal benefits from irrigating the crops which is usually been rain fed, the nutrient recovery from the reclaimed water as fertilizer, and the employment opportunities which created by the availability of the water to work in the agricultural lands.

- Marginal benefits from irrigating the crops: most the agricultural lands in served in treated water reuse project in Taybeh & Rammun towns are cultivated in olives, orchards and wheat, all these crops are rainfed, but when the crops are irrigated with reclaimed water the crop production will improve and also the benefits will increase, the marginal benefits are calculated by estimating the area cultivated in the crop and then multiplying it by the difference between the benefits from the crops which are rainfed and the benefits from irrigating the crops, in both towns the estimated agricultural area served by the reuse project and is cultivated in olives, orchards and wheat are (300,50,120) dunum respectively. Table5-31 illustrates the benefits per dunum for every crop with and without the reuse project:

Table 5-31: Marginal benefits from the reuse project (GFA, 2015,Mizyed, 2013).

Crop	olives		Almonds		Wheat	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Net benefits (NIS/dunum)	708	1,965	3,382	6,539	453	830
Marginal benefits (NIS/dunum)	1,257		3,157		377	

The marginal benefits from irrigating the olive trees are illustrated in Table5-32.

Table 5-32: Marginal benefits from irrigating olives in Taybeh & Rammun.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Marginal benefits from irrigating olives (NIS/dunum.year)	1257	1257	1257	1257	1257	1257	1257	1257	1257	1257
Number of dunums of olive	15	50	53	55	57	60	65	67	69	70
Benefits from irrigating olives (NIS)	18855	62850	66621	69135	71649	75420	81705	84219	86733	87990

The marginal benefit from irrigating the almonds trees is illustrated in Table5-33.

Table 5-33: Marginal benefits from irrigating almonds in Taybeh & Rammun.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Marginal benefits from irrigating Almonds (NIS/dunum.year)	3157	3157	3157	3157	3157	3157	3157	3157	3157	3157
Number of dunums of Almonds	50	50	50	50	50	50	50	50	50	50
Benefits from irrigating Almonds (NIS)	157850	157850	157850	157850	157850	157850	157850	157850	157850	157850

The marginal benefit from irrigating the wheat cereals is illustrated in table5-34, where the available land is about 120 dunum at the plain area.

Table 5-34: Marginal benefits from irrigating wheat in Taybeh & Rammun.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Marginal benefits from irrigating Wheat (NIS/dunum.year)	570	570	570	570	570	570	570	570	570	570
Number of dunums of Wheat	120	120	120	120	120	120	120	120	120	120
Benefits from irrigating Wheat (NIS)	68400	68400	68400	68400	68400	68400	68400	68400	68400	68400

Benefits from the nutrients recovery for both nitrogen and phosphorus, where the recovered nitrogen was calculated based on its concentration in the effluent (40 mg/l), and (3 mg/l) for the phosphorus, where market prices of (7.6, 8 NIS/kg) respectively for the fertilizers included the nitrogen and phosphorus, these benefits considered as environmental benefits. The following equation was used to calculate benefits:

Equation 18 : $\mathbf{B2} = \sum_{n=0}^{n} (\mathbf{ACPn} \times \mathbf{SPPn}) + (\mathbf{ACNn} * \mathbf{SPNn})$

The calculated benefits from the nutrients recovery is in tables5-36 and 5-37.

Table 5-35: Expected benefits from nitrogen recovery as fertilizer in Taybeh & Rammun.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Reclaimed water sold(m3/y)	16110	28200	29622	30570	31518	32340	33810	34158	34506	34680
Nitrogen concentration in effluent(kg/m3)	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Recovered Nitrogen(kg/y)	644	1128	1185	1223	1261	1294	1352	1366	1380	1387
Price of the Nitrogen(NIS/kg)	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
Benefit from the recovered nitrogen(NIS/y)	4897	8573	9005	9293	9581	9831	10278	10384	10490	10543

Table 5-36: Expected benefits from phosphorus recovery as fertilizer in Taybeh & Rammun.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Reclaimed water sold(m3/y)	16110	28200	29622	30570	31518	32340	33810	34158	34506	34680
phosphorus concentration in effluent(kg/m3)	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Recovered Phosphorus(kg/y)	48	85	89	92	95	97	101	102	104	104
price of the Phosphorus(NIS/kg)	8	8	8	8	8	8	8	8	8	8
Benefit from the recovered Phosphorus(NIS/y)	387	677	711	734	756	776	811	820	828	832

- The benefits from the employment were included in the costs and benefits of the irrigation of the lands, many items including the costs of the workers in the lands were taken into consideration in the marginal benefits calculations.

The total External benefits are illustrated in Table5-37.

Table 5-37: Total External benefits from the reuse project in Taybeh & Rammun.

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total external benefits (NIS)	250389	298350	302587	305412	308237	312278	319045	321673	324301	325615

5- External costs: as illustrated in the methodology, the health risks and costs is the main item in the costs, the vaccinations costs are calculated as illustrated in Table5-38.

Table 5-38: Costs of vaccinations for the farmers in Taybeh & Rammun reuse project.

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
No. of farmers	350	359	368	377	386	396	406	416	426	437
No. of farmers to take vacciations	350	9	9	9	9	10	10	10	10	11
price of diptheria vaccinations (NIS)	5	5	5	5	5	5	5	5	5	5
price of HAV & HBV vaccinations (NIS)	22	22	22	22	22	22	22	22	22	22
Total costs (NIS)	9247	231	237	243	249	255	262	268	275	282

The costs to benefits difference for the external items are illustrated in Table5-39.

Table 5-39: Costs- Benefits for the external items of the reuse project in Taybeh & Rammun.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
CBA for the external items(NIS)	241142	298118	302350	305169	307988	312022	318783	321405	324026	325333

From Table5-39 we can conclude that the external benefits exceed the external costs, so the social and environmental benefits are higher than the costs, which will have very positive effects on the people and farmers.

The net present value:

The net present values for the costs and benefits are calculated and illustrated in the Table5-40.

Table 5-40: NPV for Taybeh & Rammun reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total internal costs (NIS)	-896779	-64704	-66021	-67141	-68278	-69377	-70785	-71707	-72648	-73530
Total internal benefits (NIS)	16110	28200	29622	30570	31518	32340	33810	34158	34506	34680
Total external costs (NIS)	-9247	-231	-237	-243	-249	-255	-262	-268	-275	-282
Total external Benefits (NIS)	250389	298350	302587	305412	308237	312278	319045	321673	324301	325615
Cashflow	-639527	261614	265951	268598	271228	274986	281808	283856	285884	286483
NPV (NIS)	**1249206**									

From the previous table the NPV for Taybeh & Rammun reclaimed water reuse project is **1,249,206** (NIS), which is positive value and implies that the reuse project is justified to be implemented.

Table 5-41: B/C for Taybeh & Rammun Reclaimed Water Reuse Project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total Costs	-906026	-64936	-66258	-67384	-68527	-69632	-71046	-71975	-72923	-73812
Total Benefits	266499	326550	332209	335982	339755	344618	352855	355831	358807	360295
Costs NPV	-1331634									
Benefits NPV	2580840									
B/C	**1.94**									

- From Table5-41 it can be noted that the B/C ratio for AlTaybeh and Rammun reuse project is **1.94**, which indicates that the reuse project is justified.

5.3 Al Taybeh & Rammun Reclaimed Water Use in Concrete Mixing Industry

As illustrated in the previous section, this study suggests two alternatives for the reclaimed water reuse project, one is discussed in the previous section (restricted irrigation), the second is the reuse of the reclaimed water in the industry (ready mix concrete) where there is major concrete mixing company (Al Mazraa Al Sharqya company for ready mix concrete) which is about 1 km away from the WWTP, due to the lack of water resource this company can buy all the treated water to use it for concrete mixing.

5.3.1 Costs and benefits quantification:

This type of projects includes internal costs and benefits, where we can neglect the external costs and benefits because they are relevant to the industry.

- Internal benefits: it includes the benefits from selling the reclaimed water to the factory, all the generated treated water will be taken by the factory to cover the water shortage in the factory, the benefits will be calculated upon reclaimed water tariff of 1 NIS/m^3, so as to compare the results with the irrigation reuse project, the calculated benefits are illustrated in Table5-42.

Table 5-42: Internal benefits from selling the reclaimed water to the concrete mixing project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Treated water Generated (m3/y)	18250	56940	59979	61559	63181	64845	66553	68306	70105	71952
Reclaimed water sold(m3/y)	18250	56940	59979	61559	63181	64845	66553	68306	70105	71952
Reclaimed water price(NIS)	1	1	1	1	1	1	1	1	1	1
Benefits from reclaimed water sold(NIS)	18250	56940	59979	61559	63181	64845	66553	68306	70105	71952

- Internal Costs: including the investment costs for the convyance, storage, pumps and tertiary treatment for the efluent, the depreciation costs and the operation and maintenance costs for the pumps.

For the investment and depreciation costs, the project will inlude pumping the reclaimed water from the WWTP by one centrifugal pump with transmisssion 4” PE pipeline from the WWTP to storage tank of 500 m^3, and another 4” PE pipeline from the storage tank to the concrete mixing factory, Table5-43 illustrates the costs of the pipes and fittings with depreciation rate of 2.5% per year.

Table 5-43: Pipes and fittings costs for the industrial reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment cost (NIS)	64000	0	0	0	0	0	0	0	0	0
Depreciation rate	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Depreciation cost(NIS)	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600

The costs of one 500m3 storage tank is illustrated in Table5-44.

Table 5-44: Storage costs for the industrial reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment cost (NIS)	100000	0	0	0	0	0	0	0	0	0
Depreciation rate	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Depreciation cost(NIS)	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500

The costs of one centrifugal pump is illustrated in Table5-45.

Table 5-45: Pump costs for the industrial reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment cost (NIS)	20000	0	0	0	0	0	0	0	0	0
Depreciation rate	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Depreciation cost(NIS)	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500

The costs of the tertiary treatment is illustrated in Table5-46.

Table 5-46: Tertiary treatment costs for the industrial reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment cost (NIS)	350000	0	0	0	0	0	0	0	0	0
Depreciation rate	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Depreciation cost(NIS)	8750	8750	8750	8750	8750	8750	8750	8750	8750	8750

The electricity costs is considered as the operation and maintenance costs, because there is one beneficiary which is the company, so no need for someone to operate the network, just the operator of the WWTP can operate the pumps, the electrcity consumption for the pump is calcualted and found to be 0.3 NIS/m^3. Table5-47 illustrates the operation and maintenance costs.

Table 5-47: Operation and maintenance costs for the industrial reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Reclaimed water pumped (m^3)	18250	56940	59979	61559	63181	64845	66553	68306	70105	71952
Electricity Cost (NIS/m^3)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Electricity Costs (NIS)	5475	17082	17994	18468	18954	19453	19966	20492	21032	21586

The total costs , benefits , cashflow and the NPV for the reuse project is illustrated in Table5-48.

Table 5-48: NPV for the industrial reuse project

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total internal benefits yearly (NIS)	18250	56940	59979	61559	63181	64845	66553	68306	70105	71952
Total internal costs yearly (NIS)	-554825	-32432	-33344	-33818	-34304	-34803	-35316	-35842	-36382	-36936
Cash flow for the reuse project (NIS)	-536575	24508	26635	27741	28876	30041	31237	32464	33724	35016
NPV for the Project (NIS)	**-310512**									

As illustrated in Table5-48, the costs exceed the benefits, especially in the first year due to the high investment costs, as a private sector reuse project, the local village council should at minimum to recover the costs related to the reuse project, so the reclaimed water tariff should be adjusted to **1.7** NIS/m^3 so as to recover the costs and make the NPV for the project to be positive, the following table illustrates the calculation made after the modification.

Table 5-49: NPV for the industrial reuse project after modification of the reclaimed water tariff to 1.7 NIS/m^3.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total internal benefits yearly (NIS)	31025	96798	101965	104651	107407	110236	113140	116120	119179	122318
Total internal costs yearly (NIS)	-554825	-32432	-33344	-33818	-34304	-34803	-35316	-35842	-36382	-36936
Cash flow for the reuse project (NIS)	-523800	64366	68621	70833	73103	75433	77824	80278	82797	85383
NPV for the Project (NIS)	**6077**									

From the previous table, the NPV is positive and shows very little marginal benefits, but the reuse project is relatively justified.

5.3 Alteereh reclaimed water reuse project:

Determine scope and objectives:

The reuse of reclaimed water project aimed at raise the productivity of the rain fed lands in Alteereh to produce more food, increase the farmer's income, and increase the reclamation of the agricultural lands in both towns and to protect Ein qinya spring which considered as recreational place for tourists.

The constrains identification

Alteereh MBR WWTP produce treated water with high quality of (10, 10,10) mg/l as BOD, TSS and TN respectively, this quality match the PSI grade A for the use of the reclaimed water in irrigation, so the treated water can be used in unrestricted irrigation.

The availability of cultivated lands is considered as constrain, due to the geographical nature of the village where it is located between mountains and limited plain lands available to cultivate cereals.

The alternatives identification

The AMBR now produces about 1200 m^3/d of treated water, which can be used in unrestricted irrigation, the available lands in mountains are cultivated in olives, almonds and figs, and the plain areas cultivated with field crops.

The proposed reuse project in this study is to implement reuse water network with one storage tank for the higher lands, and one transmission line from AMBR to the village where we can save the pumping costs, in Figure 24 illustration about the proposed project.

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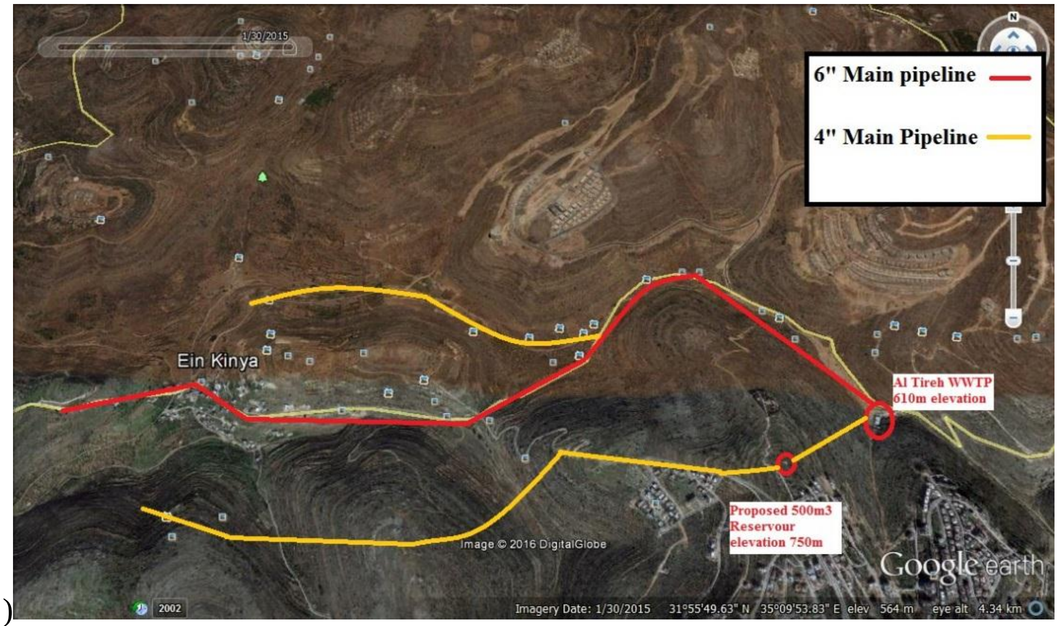

Figure 24: plan for the AMBR proposed reuse project.

Cost and benefit identification

The costs involving the proposed irrigation project include the following items:

- Investment costs for the reuse project (pump, storage and conveyance).
- Operation and maintenance costs, for the pumps and the distribution network.
- Depreciation costs, as every item of the reuse project have service life and then should be replaced.

The benefits from the irrigation project are:

- Improved crop production due to the use of the reclaimed water.
- Nutrients provided by the reclaimed water which can reduce the fertilizers costs.
- Employments opportunities as the reuse project will need staff for operation and maintenance and the availability of reclaimed water to use in agriculture will push people to work more in their lands.

Cost and benefit quantification

The internal costs and benefits will be quantified as the quantity of reclaimed water used in irrigation of available lands, the costs of the pumps, pipes, storage and conveyance system, also the operation and maintenance costs including one operator for the operation and maintenance of the system, the electriciy used in operatong the pumps will be estimated as the average pumping costs for the storage reservoiur is 0.3 NIS/m^3, we found that most of the agricultural lands are mainly planted with olives, almonds and figs beside the felid crops in the plain areas. The estimated area which can be served with the reuse network is about 500 dunums. Data about the costs and revenues from planting every type of plants were taken from the GFA study which was estimated based on water service fees of 1 NIS/m^3 of reclaimed water.

The costs and benefits for the reuse project were calculated as follows:

1- Internal Benefits:

- the benefits from selling the treated effluent from the wastewater treatment plant, where not all the reclaimed water will be utilized by the farmers, the number of available dunums to be irrigated will be estimated, and the needed quantities of reclaimed water will be calculated compared to the available treated water and the irrigated lands.

  The expected reclaimed water generated is calculated using the exponential growth equation as follows:

  $Qn = Q_0 \times e^{n*r}$

  Where:

  Qn : The Expected Quantity of treated water at year n (m^3/yr).

  Q_0 : The Quantity of Treated water at year 0 (m^3/yr).

  n : Number of Years.

r : natural population growth rate 2.6%/yr.

Data taken from the local village council about the available lands to be irrigated and the crops cultivated in these lands, these data were used to estimate the expected reclaimed to be used in irrigation yearly, Figure 25 used to determine the quantities of reclaimed water to be used as an example for the year 2025.

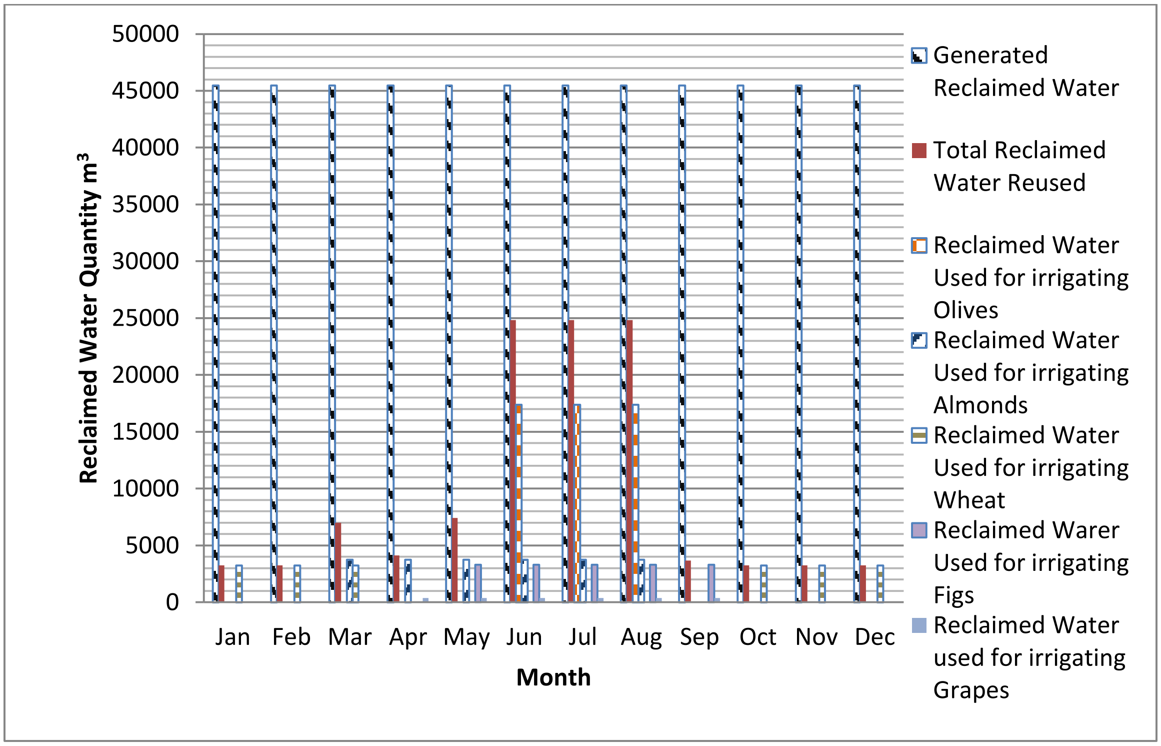

Figure 25 Expected Reclaimed Water Reuse in Alteereh during the year 2025.

The Expected quantities of reclaimed water generated and the expected reclaimed water to be reused results are illustrated in the Figure26.

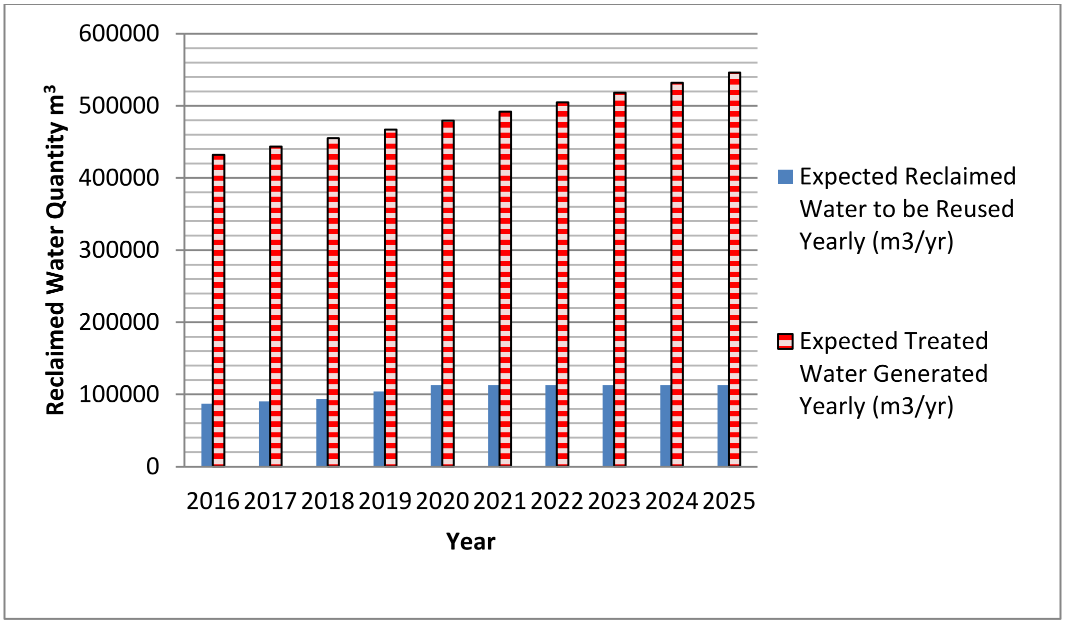

Figure 26: Expected Reclaimed Water Generated and Reused Yearly (m3/yr) in Alteereh.

The benefits from selling the reclaimed water to the farmers are calculated upon the reclaimed water tariff of 1 NIS/m^3. Table5-50 shows the calculated benefits yearly.

Table 5-50: The benefits from selling the Reclaimed Water for Farmers in Alteereh.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Treated water (M^3/Y)	432000	443379	455058	467045	479347	491974	504933	518233	531884	545894
Reclaimed Water Sold (M^3/Y)	87300	90300	93915	104250	112950	112950	112950	112950	112950	112950
Reclaimed Water Price(NIS)	1	1	1	1	1	1	1	1	1	1
Benefits from Reclaimed Water Sold (NIS)	87300	90300	93915	104250	112950	112950	112950	112950	112950	112950

- Internal costs: investment costs and operation and maintenance costs for the reuse projects.
- Investment cost: : including the pumps, reservoirs, pipes and fittings, civil and installation works and if there is any need to additional treatment process, the following equation used for the calculation of the investment cost.

CI= $(Np * Pp) + (Ns * ps) + (Cf * Pf) + (Ct * Pt)$

Dc= $\frac{1}{n} \times$ CI

Tables 5-51 to 5-57 illustrate the items of the reuse project with its related costs:

- Conveyance system: which include the pipes, fittings and installations of the reuse network, also the depreciation costs were calculated based on the data taken from Table (5-2) where the conveyance system average service life is 40 years. Table5-51 illustrates the costs of the reuse network.

Table 5-51: Conveyance system costs **(PARC, 2013)**.

Item	Quantity	Unit	Price of unit (NIS)	Total (NIS)
PE 6"	6000	m	50	300000
PE 4"	5500	m	27	148500
PE 2"	10000	m	6.75	67500
PE 32mm	20000	m	2.7	54000
PE 16mm	10000	m	1.35	13500
Fittings and Installation	LS	NA	NA	115000
Total Fittings				698500

The depreciation rate for the coveyance system is 2.5% per year. Table5-52 illustrates the depreciation costs for the coveyance system.

Table 5-52: Depreciation costs for the coveyance system in Al Teereh.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment Cost (NIS)	698500	0	0	0	0	0	0	0	0	0
Depreciation Rate	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Depreciation Cost (NIS)	17463	17463	17463	17463	17463	17463	17463	17463	17463	17463

- Storage : including 500 m^3 metallic storage tank used for the storage of treated wastewater, then the treated wastewater flows by gravity to the farmers in the high areas, the depreciation cost calculated as the average service life of 40 years, the investment cost for the tank is 100,000(NIS) with depreciation rate of 2.5% per year. Table5-53 illustrates the costs related to storage.

Table 5-53: Costs of Storage system at Alteereh reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment Cost (NIS)	100000	0	0	0	0	0	0	0	0	0
Depreciation Rate	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Depreciation Cost (NIS)	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500

- Pumps: centrifugal pump is used to lift the treated wastewater from the treatment plant to the storage tank, the investment cost of the pumps is 30,000 (NIS), and the average service life of it is 8 years with depreciation rate of 12.5% per year. Table5-54 illustrates the costs related to the pump.

Table 5-54: Costs of the reclaimed water pump at Alteereh reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment Cost (NIS)	30000	0	0	0	0	0	0	0	0	0
Depreciation Rate	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Depreciation Cost (NIS)	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750

- Operation and maintenance costs: the operation and maintenance of the reuse system can be done by one employee, also the needed parts cost for the maintenance can be recovered from the users, so the employee has a monthly salary of 2,200 (NIS) with an annual increase rate of 2.5%. Table5-55 illustrates the calculated costs related to the operation and maintenance of reuse scheme.

Table 5-55: O&M costs for Alteereh reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Increase Rate of Salary	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Total salary Yearly (NIS)	26400	27060	27736.5	28429.9	29140.7	29869.2	30615.9	31381.3	32165.8	32970

- The electricity costs for the operation of the pump is calculated to be with average value of 0.3(NIS/m^3), because the storage tank is located 1km away at 140m elevation difference, where just about 30% of the reclaimed water used is pumped because the AMBR WWTP located at higher elevation than most of the agricultural lands, and just about 30% of lands located in elevation higher than the

AMBR WWTP, so the electricity costs of pumps are calculated as illustrated in Table5-56.

Table 5-56: Electricity costs for the pumping system in Alteereh reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Reclaimed Water Pumped (M^3/Y)	26190	27090	28174.5	31275	33885	33885	33885	33885	33885	33885
Electricity cost (NIS/M^3)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Electricity costs (NIS/Y)	7857	8127	8452	9383	10166	10166	10166	10166	10166	10166

- The total internal costs are illustrated in Table5-57.

Table 5-57: Total internal costs for Alteereh reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total Internal Costs Yearly (NIS)	886470	58900	59901	61525	63019	63747	64494	65259	66044	66848

After comparing the Total internal costs and benefits we found that the reuse project is feasible, as the benefits are higher than the costs, but in the first year we can see that the costs are higher than the benefits because of the investment costs, but usually these costs are covered by the donors so we can neglect the investment costs if donor implement the project. Table5-58 illustrates the costs- benefits difference.

Table 5-58: CBA for Internal items of the reuse project in Alteereh.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Cost-Benefits for Internal Items (NIS)	-799170	31401	34014	42725	49931	49203	48456	47691	46906	46102

From Table5-58 we can conclude that the reuse project is very acceptable and feasible, if it is implemented by donors or the government, as the reuse project can generate additional income for the local village council, this can encourage the village council to invest in increasing the expansion of the reuse network so as to increase the rehabilitation of the agricultural lands.

- External benefits: as illustrated in the methodology, the external benefits including the marginal benefits from irrigating the crops which is usually been rain fed, the nutrient recovery from the reclaimed water as fertilizer, and the employment opportunities which created by the availability of the water to work in the agricultural lands.

- Marginal benefits from irrigating the crops: most the agricultural lands in served in treated water reuse project in Ein qinya village is cultivated in olives, orchards and field crops, all these crops are rainfed, but when the crops are irrigated with reclaimed water the crop production will improve and also the benefits will increase, the marginal benefits are calculated by estimating the area cultivated in the crop and then multiplying it by the difference between the benefits from the crops which are rainfed and the benefits from irrigating the crops, in Ein Qinya village the estimated agricultural area proposed to be served by the reuse project and is cultivated in olives, orchards and wheat are (250,75,130) dunum respectively, but because there is surplus of reclaimed water all over the year, many other types of trees can be cultivated in this area, but due to the weather conditions the grapes and figs is proposed to be cultivated in the area, the following table illustrates the benefits per dunum for every crop with and without the reuse project:

Table 5-59: Marginal benefits from the reuse project (GFA, 2015, Mizyed, 2013).

Crop	**olives**		**Almonds**		**Wheat**		**Figs**		**Grapes**	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Net benefits (NIS/dunum)	708	1965	3382	6539	453	830	1632	3887	1889	3669
Marginal benefits (NIS/dunum)	1,257		3,157		377		2,255		1,780	

The marginal benefits from irrigating the olive trees are illustrated in Table5-60.

Table 5-60: Marginal benefits from irrigating olives in Alteereh.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Marginal benefits from irrigating olives (NIS/dunum.year)	1257	1257	1257	1257	1257	1257	1257	1257	1257	1257
Number of dunums of olive	200	200	210	250	300	250	250	250	250	250
benefits from irrigating olives (NIS)	251400	251400	263970	314250	377100	314250	314250	314250	314250	314250

The marginal benefit from irrigating the almonds trees is illustrated in the Table5-61.

Table 5-61: Marginal benefits from irrigating Almonds in Alteereh.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Marginal benefits from irrigating Almonds (NIS/dunum.year)	3157	3157	3157	3157	3157	3157	3157	3157	3157	3157
Number of dunums of Almonds	60	65	70	75	75	75	75	75	75	75
Benefits from irrigating Almonds (NIS)	189420	205205	220990	236775	236775	236775	236775	236775	236775	236775

The marginal benefit from irrigating the wheat cereals is illustrated in Table5-62.

Table 5-62: Marginal benefits from irrigating Wheat in Alteereh.

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Marginal benefits from irrigating Wheat (NIS/dunum. year)	377	377	377	377	377	377	377	377	377	377
Number of dunums of Wheat	120	120	120	130	130	130	130	130	130	130
Benefits from irrigating Wheat (NIS)	45240	45240	45240	49010	49010	49010	49010	49010	49010	49010

The marginal benefit from irrigating the Figs trees is illustrated in Table 5-63.

Table 5-63: Marginal benefits from irrigating Figs in Alteereh.

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Marginal benefits from irrigating Figs (NIS/dunum. year)	2,255	2,255	2,255	2,255	2,255	2,255	2,255	2,255	2,255	2,255
Number of dunums of Figs	50	50	50	50	50	50	50	50	50	50
Benefits from irrigating Figs (NIS)	112750	112750	112750	112750	112750	112750	112750	112750	112750	112750

The marginal benefit from irrigating the Grapes trees is illustrated in Table5-64.

Table 5-64: Marginal benefits from irrigating Grapes in Alteereh.

year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Marginal benefits from irrigating Grapes (NIS/dunum. year)	1,780	1,780	1,780	1,780	1,780	1,780	1,780	1,780	1,780	1,780
Number of dunums of Grapes	20	20	20	20	20	20	20	20	20	20
Benefits from irrigating Grapes (NIS)	35600	35600	35600	35600	35600	35600	35600	35600	35600	35600

- Benefits from the nutrients recovery for both nitrogen and phosphorus, where the recovered nitrogen was calculated based on its concentration in the effluent (10 mg/l), and (3 mg/l) for the phosphorus, where market prices of (7.6, 8 NIS/kg) respectively for the fertilizers included the nitrogen and phosphorus, these benefits considered as environmental benefits. the following equation was used to calculate benefits:

$$B2 = \sum_{n=0}^{n} (ACPn \times SPPn) + (ACNn * SPNn)$$

The calculated benefits from the nutrients recovery are in tables5-65 and 5-66.

Table 5-65: Expected benefits from nitrogen recovery as fertilizer in Alteereh.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Reclaimed water Used(m^3/y)	87300	90300	93915	104250	112950	112950	112950	112950	112950	112950
Nitrogen concentration in effluent(kg/m^3)	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Recovered Nitrogen(kg/y)	873	903	939	1043	1130	1130	1130	1130	1130	1130
Price of the Nitrogen(NIS/kg)	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
Benefit from the recovered nitrogen(NIS/y)	6635	6863	7138	7923	8584	8584	8584	8584	8584	8584

Table 5-66 : Expected benefits from phosphorus recovery as fertilizer in Alteereh.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Reclaimed water Used(m^3/y)	87300	90300	93915	104250	112950	112950	112950	112950	112950	112950
Phosphorus concentration in effluent(kg/m^3)	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Recovered Phosphorus(kg/y)	262	271	282	313	339	339	339	339	339	339
price of the Phosphorus(NIS/kg)	8	8	8	8	8	8	8	8	8	8
Benefit from the recovered Phosphorus(NIS/y)	2095	2167	2254	2502	2711	2711	2711	2711	2711	2711

- The benefits from the employment were included in the costs and benefits of the irrigation of the lands, many items including the costs of the workers in the lands were taken into consideration in the marginal benefits calculations.

The total External benefits are illustrated in Table5-67.

Table 5-67: Total External benefits from the reuse project in Alteereh.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total benefits (NIS)	643140	659225	687942	758810	822530	759680	759680	759680	759680	759680

Note that the external benefits increasing with the time due to the increase in the quantity of reclaimed water used in irrigation.

- External costs: as illustrated in the methodology, the health risks and costs is the main item in the costs, the vaccinations costs are calculated, information taken from the local village council about the approximately number of farmers working in the targeted area, the costs are calculated as illustrated in Table5-68.

Table 5-68: Costs of vaccinations for the farmers in Alteereh reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
No. of farmers	500	513	525	538	552	566	580	594	609	624
No. of farmers to take vacciations	321	13	13	13	13	14	14	14	15	15
price of diptheria vaccinations (NIS)	5	5	5	5	5	5	5	5	5	5
price of HAV & HBV vaccinations (NIS)	22	22	22	22	22	22	22	22	22	22
Total costs (NIS)	8481	330	339	347	356	365	374	383	393	402

The costs to benefits difference for the external items are illustrated in Table5-69.

Table 5-69: Costs- Benefits for the external items of the reuse project in Alteereh.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
External Costs (NIS/yr)	8481	330	339	347	356	365	374	383	393	402
External Benefits (NIS/yr)	643140	659225	687942	758810	822530	759680	759680	759680	759680	759680
CBA for the External Items	634659	658895	687603	758463	822174	759315	759306	759297	759287	759278

From table5-69 we can conclude that the external benefits exceed the external costs, so the social and environmental benefits are higher than the costs, which will have very positive effects on the people and farmers.

The net present value:

The net present values for the costs and benefits are calculated and illustrated in the table5-70.

Table 5-70: NPV for Alteereh reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total internal costs (NIS)	-886470	-58900	-59901	-61525	-63019	-63747	-64494	-65259	-66044	-66848
Total internal benefits (NIS)	87300	90300	93915	104250	112950	112950	112950	112950	112950	112950
Total external costs (NIS)	-8481	-330	-339	-347	-356	-365	-374	-383	-393	-402
Total external Benefits (NIS)	643140	659225	687942	758810	822530	759680	759680	759680	759680	759680
Cashflow	-164510	690295	721617	801188	872106	808518	807762	806988	806194	805380
NPV (NIS)	**5172963**									

From the previous table the NPV for Alteereh reclaimed water reuse project is **5,172,963** (NIS), which is positive value and implies that the reuse project is justified to be implemented.

The B/C ratio is calculated as illustrated in the following table.

Table 5-71 : B/C ratio for Alteereh reuse project.

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total Costs (NIS)	-894950	-59230	-60240	-61872	-63374	-64112	-64868	-65642	-66436	-67250
Total Benefits (NIS)	730440	749525	781857	863060	935480	872630	872630	872630	872630	872630
Costs NPV	-1281134									
Benefits NPV	6454096									
B/C	**5.04**									

From Table 5-71 it can be noted that the B/C ratio for Alteereh project is **5.04** which is very high, and indicates that the project is strongly justified, as the benefits are very high compared to the costs.

6 CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

Analysis of reclaimed water reuse projects should consider the monetary and non-monetary aspects. This study aimed at implementing CBA of three selected reuse projects in Palestine, variable CBA data were obtained considering the treatment technologies applied, reclaimed water quality and quantity, and the availability of agricultural land. Hence, CBA for planned reuse projects should be evaluated on a case by case basis.

- Anza reclaimed water reuse project CBA shows that the internal costs which should be covered by the local village council is higher than the internal benefits, but when consider the external benefits which is much higher than the external benefits and made the CBA for project to be positive, **1,150,380** (NIS) is the NPV for the reuse project in irrigation of the agricultural lands during the period of 10 years. This implies that the government should support the village council and the farmers in implementing the project by covering the internal costs (investment costs, depreciation costs and operation and maintenance costs), so as to get the benefits from the treated effluent which is considered as wastewater flows into the streams without any use. The main constraint of the project is the limited treated effluent quantity especially during the summer period. The C/B ratio for this project obtained is **2.55** which indicate that the project is justified as the benefits are nearly more than the double of the costs.

- Al Taybeh and Rammun reclaimed water reuse project CBA shows that the internal costs are higher than the internal benefits, where the local village council should cover this difference, but considering the external benefits which are higher than the costs of the project, **1,249,206** (NIS) is the NPV for the reuse project in irrigation of the agricultural lands during the period of 10 years, this implies that the government should support the village council and the farmers in implementing the project by covering the internal costs (investment costs, depreciation costs , operation and maintenance costs and the advanced treatment costs), so as to get the benefits from the treated effluent which is considered as wastewater flows into the streams without any use. The main constraints of the project are the effluent quality which is not matching the PSI requirement for reuse in irrigation and the limited treated effluent quantity especially during the summer period. The C/B ratio for the reuse project in irrigation obtained is **1.94** which indicates that the project benefits are more than the costs, and gives a good indication about the project justification. But it is noted that the C/B ratio for AL Taybeh and Rammun project is the least as a result of the tertiary treatment costs involved in this project, due to the low treated wastewater quality from the WWTP which does not match the PSI standards for reuse in irrigation.

- The second alternative for the reuse project in Al Taybeh and Rammun reclaimed water reuse project is using the reclaimed water in concrete mixing industry, where there is one concrete mixing factory near the WWTP and can take all the generated reclaimed water due to the water shortage in the area, after calculating the costs and benefits of the project, it was found that it did not have external costs and benefits (environmental and social), so just the internal costs and benefits had been calculated upon the tariff of 1 NIS/m^3, then the NPV for the project found to be **-315512** (NIS), which negative value and shows that the project is not justified, but after adjusting the reclaimed water tariff to 1.7 NIS/m^3, the NPV for the project converted to be **6077** (NIS), which is positive value but also low benefit value, so the reuse project in AL Taybeh and Rammun in restricted irrigation is more justified.

- Alteereh reclaimed water reuse project which targets to irrigate the agricultural lands in Ein Qinya village, the CBA shows that the internal benefits are higher than the internal costs except the first year, where the investment costs are very high, so the government should support the village council in implementing the project and then the village council can operate the project with marginal benefits which can add economic source of money for the local village council, **5,172,963** (NIS) is the NPV of the reuse project in irrigation of the agricultural lands during the period of 10 years, which is high value and shows that the project is strongly justified to be implemented so as to get benefit from the treated water which is considered as wastewater and flows from the WWTP to the stream. The main constraint of the reuse project is the availability of agricultural lands and the allowed types of crops according to the PSI, which does not allow the farmers to irrigate the vegetables with treated effluent. The C/B ratio obtained for this project is **5.04** which indicate that the project is strongly justified as the benefits are five times of the costs.

We can conclude that In Palestine, reclaimed water reuse projects not only have high economic importance but also the socio-political issues play an important role in reclaimed water reuse projects sustainability, as it reduces the unemployment rates and increases the connection between the people and their lands.

We can’t neglect the political importance of reclaimed water reuse projects, as it supplies the farmers with sustainable Palestinian controlled water source, which reduces the dependency on the occupation water sources and leads to reclaim the unused agricultural lands and protect the endangered in confiscation lands especially in area C.

Recommendations

- The CBA criteria, developed in this study should be applied in the reclaimed water reuse projects, choosing the most beneficial project shall guarantee sustainable use of reclaimed water.

- Considering the PSI standards for reclaimed water reuse before choosing the WWTP technology, so as to select the technology that meets the requirements for irrigation; this can minimize the costs related to further treatment.

- To ensure a successful strategic framework for reuse project, public consultation and raising awareness campaigns should start at early project stage.

- Governmental subsidization should be endorsed, since the local councils can't bear the investment and operation costs, to assure the sustainability of the projects.

- During summer periods, more water demand for irrigation is needed, therefore, capital expenditures for the construction of storage reservoirs urging for financial support by the government and donors

- To reduce annual operational expenditures of pump systems, installation of renewable energy sources (solar panels) warrant further studies.

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