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I, Eyad Y. A. Yaqob Ph.D., hereby submit this original work as part of the requirements for the degree of Doctor of Philosophy in Environmental Engineering.

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Student’s name: Eyad Y. A. Yaqob Ph.D.

This work and its defense approved by:

Committee chair: George Sorial, Ph.D.
Committee member: Hafiz Saileh, Ph.D.
Committee member: Margaret Kupferle, Ph.D., P.E.
Committee member: Makram Suidan, Ph.D.
"Prospects for a Shared Management of Transboundary Wastewater: Israel-Palestine Case"

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by

Eyad Yacoub Yaqob

B.Sc, Civil Engineering, Birziet University, West Bank, Palestine, 1997
M.Sc, Water and Environmental Engineering, Birziet University, West Bank, Palestine, 1999

Research Committee

Dr. George Sorial (chair)

Dr. Makram Suidan

Dr. Margaret Kupferle

Dr. Hafiz Saleh
Abstract

Water is essential for life, and any lack of this important element in our life leads to problems, physiologically as well as politically and economically. The deficiencies in ground water sources, global climate change, and civil pollution has led to the emergence of a real water crisis in many regions of the world. Non-traditional sources of water represent the promised solution to the scarcity of natural water sources and will represent complementary sources of supply. The main objective of this research is to study the technical, financial, and managerial aspects for transboundary wastewater. The first part of this research concentrates on the situation analysis and on the perspectives of transboundary wastewater management along the Israel/Palestine borders. Results obtained revealed that the current bi-national agreement does not achieve environmental justice and protection. A regional cooperative framework with a clear coordination mechanism considering the international experience with transboundary wastewater management and engagement of NGOs and donor countries is needed. The second part of this research explores the financial challenges facing the Palestinians to manage the transboundary wastewater crossing the Palestinian territories (West Bank) into Israel by examining the main transboundary wastewater stream, Wadi Al-Zomer, in terms of its quantity, quality and comparing the cost and benefit of wastewater being treated in Israel versus being treated in West Bank. The total amount of discharged wastewater in the targeted stream is 11 MCM/year. Discharged wastewater that reaches to Israel is not classified as highly strength wastewater due to the natural treatment adopted in the West Bank. Treating and reusing of the wastewater from all transboundary streams will increase the volume of water available for agricultural in the West Bank by 12%. The third part of this research represents the simulation of transboundary
wastewater resource management scenarios in the Wadi Zomer watershed, using the WEAP model. The results show that the amount of treated wastewater in the study area will reach 16 MCM by 2035. The agricultural sector needs 17 MCM and currently only 2.8 MCM are available from artesian wells. The results also showed that one of the reasons for not using treated wastewater is a lack of experience in the planning and selection of wastewater treatment plant sites and capacity to match with agricultural land that could reuse the treated wastewater. The last part of this research examines the cost–benefit analysis model for wastewater reuse in agriculture for four Palestinian case studies. It presents the cost and benefit analysis (CBA) of treated wastewater use in Palestine, while focusing on four types of famous crops (fodder, palm, olive, and almond trees) taking into considerations three different locations for wastewater treatment plants (WWTPs). Results obtained indicate that the use of one million cubic meters (MCM) of TWW in palm cultivation results in financial returns of US$2 million. Meanwhile, the irrigation of fodder, olive, and almond trees achieve about US$1 million per MCM of TWW.
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To my wife, Inas
CHAPTER 1

Statement of the Problem

Not subject to political boundaries, transboundary environmental issues in general and transboundary water bodies in particular are the focus of recent research studies of environmentalists. Worldwide, there are 276 international river systems covering about 45% of the earth’s land surface and supporting 40% of the world population (De Stefano et al., 2012). Considering the 145 countries with shared international river systems, 92 of them have 50% of their territories in these basins (Rieu, 2014). There are 21 countries that receive 50% of their surface freshwater supply from upstream countries. Since 1814, 600 bilateral and multilateral international agreements have been signed between parties to manage water (UN, 2015). The majority of past agreements focused on navigation and recently focused on use, development, protection, and preservation of water resources. However, management of wastewater along state borders was never addressed, and if done then barely.

The United Nations provided guidance to resolve transboundary water and wastewater issues, but there is no international binding law to solve water pollution, which could cause cross-border disputes. Reaching sustainable bilateral agreements is relevant to the reduction of cross-border conflicts over transboundary water sources and wastewater management. An investigation of the diverse challenges of neighboring countries, which considers the differences in political power levels, economic situations, and operational capacities to deal with water and environmental management, is of priority.

Wastewater, a non-conventional water source, is considered one of the basic elements within the water balance in many arid and semi-arid countries. The ownership of wastewater and reclaimed water is not integrated within bilateral agreements. Hence, unsustainable management or lack of wastewater infrastructures in an upstream country can lead to a dispute with downstream countries,
where wastewater flows along its transboundary borders. This research study aimed at understanding
the importance of wastewater management flowing cross-borders between Palestine and Israel, with
emphasis on its role for food security, physical scarcity, and social security.

1.1 Introduction

1.1.1 Transboundary

Water is life, and any lack of this vital element in our lives leads to a real disaster. Therefore, the
General Assembly of the United Nations confirms that the right to clean water is a constant
human right. As a result of the growth of population and booming developments in industry and
agriculture sectors, the demand for water has increased significantly, which has led to land
depletion of water sources. The most important water inventory shortages are ground water
sources. The occurrence of climate change has led to a drought in water bodies, in addition to
pollution, and all this has led to the emergence of a real water crisis in many regions of the
world, including the Middle East. These crises may pose a direct cause of conflict in the future.
The scarcity of water due to shortages or the low quality of water is one of the most important
environmental and economic issues of concern in the Middle East.

The Middle East region covers 4.9% of the total area of the world and is populated by 4.4% of
the world's population. The water resources total 484 cubic kilometers, which represents only
1.1% of the total renewable water resources in the world. The increasing demand for water
increases the pressure on natural fresh water, which urges professionals to look for other water
sources. Non-traditional sources of water represent the promised solution to the scarcity of
natural water sources that can be complementary sources of supply. Salt water and wastewater
are from natural renewable resources.
As water has no color, taste, or smell, it also has no political, economic, or social boundaries. Water physically represents humanity’s "common future". The water issue is a fundamental issue of life because its presence means the existence of life. When shortages or mismanagement occur, this can lead to poverty and the end of life. Therefore, water earns political interest before economists determine the ways to develop water resources and control.

If we distribute the different water resources among the seven billion inhabitants of the earth to suffice their needs (100-200 liters per day/inhabitant), the available water will only be sufficient until the middle of the twenty-first century. However, it is expected that the world's population will increase during the next thirty years by 2.6 billion people, while water resources may not increase accordingly. South America acquires 26% of the global water resources, but its population represents only 6% of the total world population. North and Central America acquire only 5% of the world's water, compared to its 8% of the world population. Australia acquires only 1% of the world's water, compared to its less than 1% of the population. The share of Asia does not exceed 36% while they have 60% of the world's population. Africa has 11% of the water compared to its 13% of the population. Europe has 8% of the world's water for 13% of the world population (Nations, 2012).

The United Nations defined that transboundary water resources are “any surface or ground waters, which are located on boundaries between two or more states.” A geographical distribution of freshwater resources in the world for joint resources between two or three countries shows there are 23 basins shared by 4 to 12 countries. There is 75% or more than 50 countries’ total area located within international river basins. Between 30% and 40% of the world's population live in joint basins (Brels, Coates, and Loures, 2008).
Experts emphasize that the conflict over water is no longer an economical or developmental issue but has become a security issue. The water resource issue causes a conflict between the downstream and the upper stream countries. These conflicts could lead some countries to fall below the water poverty line. Hence, more cooperation and the formation of a unified strategy for joint water are deemed necessary. Over the years, international treaties have dealt with transboundary issues including the allocation of water quotas and the organization of navigation and fishing, construction of public facilities such as dams, and so on.

Recently, some of the treaties were modified – especially in the beginning of the seventies – to reflect the growing concern about the pollution of shared water resources. For example, the conventions on the quality of the Great Lakes in 1972 and 1978 dealt with pollution from traditional sources such as the discharge of sewage from cities, which led to severe deterioration in the low-land in the Great Lakes region and toxic pollutants, respectively. (UNESCO, 2002)

As for the situation in Palestine, the total area of agricultural land in the West Bank and Gaza Strip is about 1.835 million acres. The rain fed cultivation covers an area of 1,523 thousand acres in the West Bank and 68 thousand acres in the Gaza Strip. The irrigated agriculture covers 244 thousand acres with 127 thousand acres irrigated in the West Bank and 117 thousand acres irrigated in Gaza Strip. (PCBS, 2011). The agricultural sector in Palestine absorbs 14% of the total workforce; agricultural exports represent 30% of the total Palestinian exports and contribute to the GDP 10.7% of its relative value.

1.1.2 Israel-Palestinian Case Study

Wadi Zomer is located in the northern part of the West Bank. The region is part of the catchment area of the largest groundwater source in the region, the mountain aquifer. Though this area has
some of the highest precipitation rates in the West Bank (average 600-700mm/year), it is a region characterized by a growing scarcity of water. The main stream bed in the area is Wadi Zomer, which is used as a drain for the sewage from the towns of Nablus, Anabta, parts of Tulkarem, and the villages located on the banks of the wadi. The three dimension topography is showed in Figure 1. It is roughly estimated that half of the sewage load generated between Nablus and Tulkarem infiltrates into the groundwater. Besides the wastewater discharged into the wadi, a large portion of the sewage from houses not connected to central sewerage systems is received by cesspits also causing wastewater infiltration into the groundwater.

Figure 1. Three dimension topography
1.2 Main Objective

The primary goal of this dissertation is to develop a model of collective cooperation and reallocation of benefits to solve the conflict regarding transboundary wastewater.

The value of this dissertation lies in its demonstration of how international agreements have resolved wastewater conflicts in the past. Moreover, it suggests that such precedents may serve as templates for the resolution of the pending and future conflicts.

1.2.1 The Specific Objectives

- Situation analysis and perspectives of transboundary wastewater management along Israel/Palestine borders

Environmental problems between countries can have deep historical roots and consequences for several reasons. Most environmental transboundary problems are yet to be resolved because the solutions that were developed responded to the pressures of political, media, and environmental non-governmental organizations (NGOs), and did not respond to the needs or reality on the ground. This section focuses on transboundary wastewater management between Israel and Palestine. The measures undertaken by the government of Israel and the associated effects on solving the transboundary pollution issues are presented. Of equal importance, procedures applied by the Palestinian Authority (PA) to resolve the environmental problems are discussed. The responsibility of donor countries and local NGOs in managing the conflict are also addressed. The results reveal that the current bi-national agreement does not achieve environmental justice and protection. The government of Israel applies stringent standards and guidelines, which exceed the financial and technical capacities of the PA to achieve sustainable sanitation facilities within its district. A regional
cooperative framework with clear coordination mechanism considering the international experience on transboundary management of wastewater and engagement of NGOs and donor countries is needed.

- **Technical and financial challenges of transboundary wastewater management from the Palestinian territories (West Bank) to Israel**

The collected wastewater from the Palestinians urban communities is discharged into different wadis (valleys) without treatment. The discharged wastewater flows by gravity towards Israel. The Israeli side treats the discharged wastewater at the Palestinians’ expense (by deducting costs from the Palestinian tax money) and benefits from the treated wastewater.

Wadi Al-Zomer is the main transboundary wastewater stream that conveys the discharged wastewater from the West Bank towards the Israeli WWTPs inside the Green Line. This plant is examined in terms of its quantity and quality to compare the cost and benefit of wastewater being treated in Israel versus being treated in the West Bank.

- **Simulation of transboundary wastewater resource management scenarios in the Wadi Al-Zomer watershed using the WEAP model**

The Water Evaluation and Planning (WEAP) model is adopted to examine the Nablus and Tulkarem watershed. The model is applied to evaluate and analyze the existing balance and expected scenarios for wastewater management. The results demonstrate if the use of treated wastewater in the West Bank areas has a positive impact on the current living conditions of Palestinians. The results also demonstrate if domestic demand can be enhanced from the scenarios taken into account. Water demand management is one of the measures necessary for the proper management of available resources.
• Cost benefit analysis of the physical options model

A benefit-cost analysis will be carried out to estimate the cost of reusable treated wastewater in the study area. This section considers three options for wastewater treatment in the watershed area: construction of a treatment plant for the wastewater originating from the west Nablus area, Tulkarem area, and Emek Hefer treatment plant. The aim of this part to present the cost and benefit analysis (CBA) of treated wastewater use in Palestine focusing on four types of famous crops (fodder, palms, olive, and almond trees) at three different locations of wastewater treatment plants (WWTPs)
1.3 Dissertation Outline

The dissertation consists of six chapters. Chapter 1 provides the nature of the problem being addressed by this research. Chapter 1 also states an overview of the scientific approach and lists the goals of this research. Chapter 2 determines the stakeholder's conflict and the relationship between all parties and the roles assigned to each party as well as an analysis of the relationship and the ability of each party to solve the environmental problem. Also, a review of the international literature regarding the same case is studied in this chapter. Chapter 3 provides technical information, both from quantitative and qualitative analysis, and knowledge of the degree of treatment that is needed and determines the benefit that can be obtained from this source and the cost that we need to achieve the benefits. In Chapter 4, the use of mathematical models is set up for assessment and analysis of the available water resources in the study area. The sewage source of available water resources is modeled and evaluated in three scenarios. Emphasis was placed on providing sewage and linking them with agricultural land available and water needs for the next twenty years. In Chapter 5, the cost assessment and benefit analysis for transboundary wastewater reuse is assessed through different scenarios including four types of agricultural crops and financial yield for each crop. Several sites for sewage treatment proposed on both sides of the border and a mathematical model have been developed for simulation variables and different scenarios. Chapter 6 provides general conclusions of the research work and recommendations for action in the future.
Figure 2. Schematic diagram of the dissertation structure
CHAPTER 2

Situation Analysis and Perspectives of Transboundary Wastewater Management along Israel/Palestine Borders

Abstract

Environmental problems between countries can have deep historical roots and consequences for several reasons. Most environmental transboundary problems are yet to be resolved because the solutions that were developed responded to the pressures of political, media, and environmental non-governmental organizations (NGOs), and did not respond to the needs or reality on the ground. This paper focuses on transboundary wastewater management between Israel and Palestine. The measures undertaken by Israel, the stronger party, and the associated effects regarding the transboundary pollution issues are presented. Of equal importance, procedures followed by the weaker party, Palestine, to resolve the environmental problems are discussed. The responsibility of the donor countries and local NGOs in the conflict is also addressed. Results obtained revealed that the current bi-national agreement does not achieve environmental justice and protection. The stronger party applies stringent standards and guidelines, which exceed the financial and technical capacity of the weaker party to achieve sustainable sanitation facilities within its region. A regional cooperative framework with a clear coordination mechanism considering the international experience on transboundary management of wastewater and engagement of NGOs and donor countries is needed.

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2.1 Introduction

According to recent United Nation (UN) data, 33% of the world populations (about 2.6 billion people) have no access to adequate sanitation. The construction of facilities, wastewater management, and the promotion of hygiene require high investments that many regions cannot afford. Consequently, 80% of diseases around the world are caused by unsafe water and lack of sanitation services (UNDP, 2006). When such problems cross borders, they call for co-operation. These problems cannot be solved without cooperation between states and help from the rich to the poor countries (Jobin and Peña, 2006; Klawitter et al., 2007)

Conflict between countries is often due to the absence of binding international law to resolve environmental problems. International humanitarian law (IHL) on environmental protection during armed conflicts lacks clarity in the definition of environmental damage and lacks legal certainty regarding the protection of elements of the environment and civilian targets. Application of the principle of proportionality as harmful to the environment, "collateral damage", is also a problem (Michael et al., 2010). Conflict resolution is hampered by differences between countries in their capacity or resources to deal with decontamination problems (Dinar, 2009). Environmental transboundary conflicts frequently arise because parties’ rights and properties are unspecific and not clear. More importantly, the international law of transboundary water tackles only freshwater but includes only hints and remarks on pollution issues. In the Israeli-Palestinian case, there is no problem with the capacity of the human staff to manage the sanitation sector. This is due to the commitment of donor countries to provide training programs for Palestinian technical crews by providing part of the project funding for training and capacity building for the Albireh and west Nablus treatment plants. Thus, the solution depends on political will, not on technical issues and needs (Tobey and Smets, 1996).
It is often difficult to identify the polluter, especially regarding non-point pollution. It is also not clear legally how and when the polluter should pay, how much, and sometimes even for what. When addressing transboundary pollution, there is no central authority which can identify the polluter, mandate enforcement, or allocate property rights (V., 1999; Selby, 2007). Europe failed in the period between 1945-1987 to solve the Rhine River’s pollution problem, due to the river’s transit between several countries, poor diplomatic relations, and the lack of joint or harmonized environmental regulations and laws. After 1987, the Rhine became clean because of the available political climate and only one body applied environmental laws and regulations. Middle Eastern countries are currently experiencing what Europe suffered from for decades (Selby, 2007).

A historical perspective is useful as a reference showing how water conflicts have arisen and been approached between countries. Earlier attempts to handle transboundary water pollution problems and conditions on the ground form the baseline of future subsequent negotiations and solutions (Feitelson and Levy, 2006). Israel and Palestine need to face shared border environmental pollution problems that plague water, air, and land. This study explores the issue of sewage across the western borders of the West Bank, Palestine flowing towards Israel and to determine the actual bi-national and unilateral technical negotiations between Israel and Palestine over transboundary wastewater. There are many intricacies in the negotiated joint water treaties. The transboundary wastewater issue may give rise to cooperation, but it may also be a source of volatile behavior (Al-Sa’ed, 2010).

Research efforts on policy development for the wastewater management conflict between Israel and Palestine are still developing and most research work is confined to case studies. Only a few studies have employed conflict analysis as an integrated approach to understand and analyze how to promote sustainable wastewater management on both a local and regional scale (Brayer, 2011).
In order to examine how the parties deal with the technical side in the negotiations to resolve the transboundary pollution problem, this study explores the case of Palestinian/Israeli transboundary wastewater. The study presents and illustrates in detail the transboundary case study. Next, the paper discusses conflict analysis and the role of all stakeholders. This is followed by the parties’ response to the conflict. Finally, some conclusions and recommendations are offered about the role of political variability in determining the appeal behind the technical issues and the solution emerging from the media and political pressure. It could be claimed that the negotiation of environmental conflict is not seen in the technical aspects when drafting transboundary pollution agreements.

2.2 Methodology

The analysis of environmental conflict is the foundation for understanding the sensitivity of the conflict itself. It aims at understanding the interactions between the conflicting parties and those who assist them in resolving the dispute (PCBS, 2004-2006), and ignoring such analysis could intensify the complexity of the current situation. Subsequently, for the sake of finding a solution, this study focuses on the transboundary wastewater pollution conflict between Israel and the occupied Palestinian territory (oPt). There are many methods and procedures for addressing environmental conflict, including but not limited to negotiation, mediation, and diplomacy, that would eventually provide general solutions and guidelines on how the conflict could be resolved.

But since each case has its own specificity, these solutions will not be applicable on all cases. Accordingly, this study follows a certain approach in analyzing the conflict where the conflict history, causes, nature, and parties have been identified in the introduction and the case study sections. The conflict causes alongside the obstacles that prevented reaching a solution were
analyzed by concentrating on the conflict level, its impact on human beings’ lives, and the technical, social, and political aspects as well as the parties’ interests in this continuing conflict. Furthermore, a conflict map was used as a tool for analysis; this tool is based on defining the parties by using circles in which the circle size indicates the party’s power. The circles are linked by lines where the shape of the line and its size indicate the nature of the relationship between the parties.

In order to reach a win-win result, a stakeholder analysis (STA) was used to determine the needs of conflicting parties who have a stake and interest in reforms. It is essential to have information about stakeholders’ interests and willingness to support the solution, thus ensuring the adaptation of realistic and sustainable policies (Hipela and Walker, 2010). In the STA section, a stakeholders’ matrix, engagement towards conflict, and responses to the conflict were used as tools to understand their positions, relationships with other groups, and their desire to find suitable solutions. In the last section, win-win solutions were developed based on the analysis of the conflict and stakeholders, which helps in identifying possible negotiable strategies with the conflicting stakeholders.

2.3 The Study Area

The Oslo Agreement divided the occupied Palestinian territory (oPt) into three political areas (A, B, and C) which designate varying levels of control. Area A comprised 1,004 km² (20%) of the West Bank, Area B comprised 1,204 km² (21%) of the West Bank, and Area C constituted 3453 km² (59%) of the West Bank. The population of the West Bank is 2.6 million people in an area of 5,661 km² (Abdallah and Swaileh, 2011). The West Bank has a very high growth rate, about 2.6%, and is distributed as follows: 68.81% in urban areas, 25.79% in rural areas, and the
remaining 5.40% in refugee camps (Palestinian Ministry of National Economy in Cooperation and the Applied Research Institute, 2011).

The West Bank population generates 44.8 million m³ per year of wastewater, which implies an amount of supplied water of 55 liters per inhabitant per day. Most of the collected wastewater in the West Bank is discharged untreated into the environment. The effluent of 70.25% of the public sewage networks flows untreated into open areas while the effluent of 16% of the sewage networks is treated or pre-treated in wastewater treatment plants. The effluent of the remaining percentage (13.75%) of the sewage networks is treated in Israeli treatment plants and reused for irrigation purposes, and the other flows are untreated into open areas. This situation is aggravated by the impact of untreated wastewater that is disposed of by the 257 Israeli settlements which are in the West Bank region affecting the neighboring Palestinian villages and agricultural land. The major wastewater stream flow is in Wadi Zomer, Wadi el-Sajour (Nablus), Wadi Beitunia (Ramallah), Wadi en-Nar (Bethlehem), and Wadi as-Samen (Hebron) (B’Tselem, 2009). Figure 3 shows the transboundary area between Israel and Palestine.

The Joint Water Committee (JWC) was formed in accordance with Article 40 of the Oslo Agreement, and the parties agreed on the agenda and mechanism of the committee. Despite this agreement, the Palestinian side claims that during the previous 15 years, Israel has agreed to only one Palestinian sanitation project (Nablus West) and refused more than 25 projects which are located in area C while the Palestinians agreed to more than 30 sewage projects which service Israeli settlements in the West Bank (The World Bank, 2009).

According to official Israeli sources in 2007, Israeli colonies in the West Bank annually produce 35 million cubic meters of sewage. According to the Israel Interior Ministry, 81 Israeli colonies
out of 257 colonies inside the West Bank have wastewater treatment plant (there are 120 legal settlements and more than 100 so-called settlements called “outposts”). More than half of the treatment plants do not work and achieve the required environment standards. The Director of the Ministry’s Central District, Gideon Mazor, admitted the failure of the Ministry and of the Supreme Planning Council in the Civil Administration to prevent construction or occupancy of buildings in settlements and industrial areas in the West Bank that do not have solutions for wastewater (Land Research Center, 2008).

In a personal interview with Mr. Benny, Environment Officer in the Israeli Civil Administration, who is responsible for all the environmental wastewater projects in the West Bank, he said that all the projects submitted by the Palestinian side to the Civil Administration had been agreed to, and that all Israeli settlements in the West Bank have waste water treatment plants (Benny, 2013).

Settlements from the Israeli perspective are considered as military zones and therefore, it is difficult to get any information about its infrastructure and population. The assigned consultant for establishing a carrier line and regional wastewater for the Wadi Zomer catchment areas project funded by the German government failed to get technical information about the settlements for design purposes as the Israeli side rejected to provide any information to the consulting firm and the Palestinian side.
Figure 3 Green Line border, transboundary area
The transboundary pollution issue needs cooperation on both sides in order to solve the problems, not military force. In the Israeli-Palestinian case, the Israelis believe that military force can achieve long-term cooperation and permanent environmental protection for Israel. The JWC and the civil administration gave all necessary construction permits for the Salfit wastewater treatment plant, but the Israeli army stopped the construction and did not respect the permits issued by their own government, so the wastewater still flows to the open wadi without treatment (Schalimtzek and Fischhendler, 2009).

Since 2003 Israel deducts the expenditures of transboundary wastewater treatment from Palestinian tax money that should be returned to the Palestinian Ministry of Finance’s national budget. It should be highlighted that the Israeli treatment plants located along the Green Line are established or enlarged from the funds deducted from the Palestinian tax money that is under Israeli control and should be transferred to the Palestinian Ministry of Finance without any negotiating, agreement, or payment mechanism on the Palestinian side (Al-Sa’ed, 2010). The international community pledged US$500 million to build a sanitation infrastructure in the Palestinian territories, but the Israeli side refused to issue the necessary permits and imposed an old/new requirement which links Israeli settlements inside the West Bank to Palestinian sanitation projects funded by the international community, which is considered illegal under international law. Israel demands high quality parameters of effluent that cannot be achieved unless complicated expensive technologies are applied, equivalent to the ones used in the US and Europe and which cannot be afforded by Palestinian targeted communities.

The lack of a clear mechanism in the Joint Water Committee (JWC) to give construction permits for sanitation projects in the West Bank has helped the Israeli side force its unfair water policy on the Palestinians. This policy is not serving the purpose of a future permanent and viable
Palestinian state. Israelis are placing obstacles in the way of Palestinian sanitation projects, such as the imposition of high specifications, connecting Israeli settlements, and zero treated effluent discharge during the winter period even though Israel is establishing wastewater carrier lines from the West Bank into Israel (Wadi Qana carrier line, Ariel carrier line, etc.).

Most Palestinians observe the JWC as a continuation of Israel’s domination (Tamimi, 2011). These views are related to the veto power embedded in the Oslo B accords in the form of decision making by consensus: [All JWC agreements should be] reached by consensus, including the agenda, its procedures, and other matters (Article 40, paragraph 13; Zeitoun, 2008). Since the water treaty was signed, Palestinians have continuously experienced the Israeli veto power on their wastewater development projects: Palestinians cannot veto the Israeli water and sanitation projects in the West Bank (Area C) or on the shared resource within Israel (Isaac and Hilal, 2011). The Palestinian Water Authority published a report where meetings of the JWC were described as “continuous suffering”. The report also noted that even water and sanitation projects that were approved by the JWC were not implemented (Jon, 2011).

2.4 Conflict Analyses

The problem of transboundary pollution between Palestinians and Israelis has existed for more than 60 years and until now no sustainable solution has been found. Mainly, the problem is summarized by the fact that about 1.6 million Palestinians live in the west mountainous region (in the West Bank within a watershed area), which has a topography and nature where dry and seasonal valleys carry wastewater into Israel. Added to this are other sources of pollution to the valleys which are from the Israeli settlements in the West Bank. Recent data (Abed and Wishahi, 1999) indicated that almost 500,000 Israeli settlers live in the watershed area where raw
wastewater is being discharged into Palestinian lands and streams. This current wastewater disposal from both sides leads to the destruction of farmland, pollution of water resources, and poses public health hazards. Furthermore, while the Palestinian per capita water consumption is only 70 liters per day, the consumption of an Israeli settler is 296 liters per day as a result of Israel's control over water resources and higher living standards. (Palestinian Hydrology Group, 2003).

The problem of transboundary sewage between Palestinians and Israelis goes back to the British mandate (1917-1948), Jordanian administration era (1948-1967), and the current Israeli occupation. The Israeli government did not provide any adequate solution during the occupation period between 1967 and 1996 and have never tried to solve this issue. Since 1996 until now, transboundary wastewater arouses conflicting issues between related parties which calls for an urgent solution. According to the Oslo Agreement, Figure 4 illustrates that the West Bank has an approximate total area of 5,643 square kilometers classified into three areas of control. Area A, which represents about 20% of the West Bank, is marked by its lack of geographic connection. Areas classified as “A” are of high population density. Furthermore, the normal development of this area is limited as no flow of goods and materials is allowed except through Israeli checkpoints scattered all over the West Bank and these areas are bordered by Israeli settlements. However, inside these areas Palestine has complete control.

Area B is subject to the Palestinian civil control whereas security issues are under the control of Israelis. This category also represents about 20% of the West Bank. The area classified as Area C represents 60% of the West Bank and is under full Israeli control and represents the area of agricultural land with a low population. This category is the most important category because it is obviously the majority area of the West Bank and has a potential future for agricultural,
economic, and urban development. However, in order to have viable possibilities for wastewater treatment plant construction, the Palestinians must consider Area C for the establishment because of the availability of agricultural land for treated wastewater reuse and distance from population center. It is worth noting that any such type of construction in Area C (i.e., wastewater treatment plants, or any other buildings and construction) must obtain the approval of 14 governmental and security parties on the Israeli side, which makes the process extremely difficult and time-consuming, meaning years (Abu-Madi and Al-Sa’ed, 2009).
Figure 4: Oslo agreement geopolitical map for the West Bank (Palestine).
The conflict of transboundary wastewater was initiated between Israel and the Palestinians after the signing of the Oslo Agreement in 1996. Israelis started to claim that Palestinians needed to resolve the pollution problem as soon as possible despite the fact that Israel did not consider solutions for these issues from 1967 to 1996. Regardless of these demands, Israel has hampered all Palestinian efforts to solve the problem ever since the 1996 Oslo Agreement. Below are some obstacles caused by Israel that prevented the implementation of wastewater projects:

1. Israeli authorities through the JWC and the Civil Administration delayed and refused Palestinian requests for licenses and rejected several applications to erect wastewater treatment facilities to serve Palestinian communities [1996 until 2011].
2. The Israelis withdrew their JWC and Civil Administration consent and approvals for some Palestinian water and sanitation projects such as the sewage and drainage projects of Salfit in 1998 and Tulkarem in 2003.
3. Israel imposed stringent standards that needed huge capital investments and high annual operation, maintenance, and repair costs. All this has resulted in the inability of citizens to pay for treatment costs, making these treatment plants unsustainable.
4. Israel water law (effluent reuse) prohibits (Authority MoU, 2003) the discharge of treated wastewater into seasonal valleys despite complying with required effluent quality standards. This calls for the construction of mega-storage reservoirs, especially during the winter period, where no effluent reuse in irrigation can be practiced. Huge financial burdens and loss of valuable land are associated with such a rule, and thus cannot be implemented.

Because of the conditions listed above, none of the funded and proposed wastewater projects are being implemented, resulting in the wastewater flowing into valleys and across the border into Israel. On the one hand, the quantity of wastewater from the Palestinian side that flows through
the border is around 20 million cubic meters annually (UNDP, 2009). On the other hand, the quantity of wastewater that flows from the Israeli settlements inside West Bank is 54 million cubic meters per year which is dumped into the environment within the Palestinian West Bank (B’Tselem, 2009).

Israel has acted unilaterally and contrary to the agreements signed between the two parties, violating international law (which requires the occupier to protect the environment in the occupied territories) (ARIJ, 2004).

The four involved parties in this conflict are Israel, Palestine, donor countries, and NGOs, both local and foreign. There are varying roles and relationships between these parties regarding the problem of pollution. Israel has political and military power, economic and technical resources, and control over all aspects of life in the West Bank. In addition to controlling Palestinian day to day life, Israel as the main and stronger player in this conflict has put political pressure on the donor countries to follow its own agenda. On the other hand, Israel has to handle the tense relationship with the civil institutions because of local and international criticism of Israeli policy towards the Palestinian environment. Another aspect of this conflict is the relationship with the Palestinians. Palestine has no military and economic power and lacks sovereignty over its own resources as guaranteed by international laws. Palestinians must always seek Israeli approvals despite the concessions they made in the Joint Water Committee. The concessions from Palestinians entailed the approval to erect more than 30 sewage projects within the Israeli settlements in the West Bank as well as the construction of a main sewage trunk line from Israeli settlements into Israel [according to JWC minutes of meetings]. It is worth noting that the peace process has been stalled due to the construction of Israeli settlements which opposes international law and challenges the Palestinian leadership. The relationship between
Palestinians and donor countries is a good one in financial terms, and relations with NGOs are good because these institutions are defending environmental rights based on international law. Figure 5 shows the conflict map which explains the relation between the involved parties.

Figure 5. Conflict map
2.5 Response to the Conflict

Parties have various responses to the conflict. The Israeli response to the conflict is affected by its military and economic power, so it tries to impose conditions on the weaker party (the Palestinians). Israel truncates US$ 1,000,000 every month from Palestinian tax money without mutual agreements and neglects joint agreements and international law. Israel has also used army forces to stop the establishment of Palestinian wastewater treatment plants despite the approval of such sanitation projects by the Joint Committee. The Salfit wastewater project is an example of one of the Palestinian wastewater projects where the Israeli army tanks stopped the construction work on the site after the project obtained all necessary permits from the Israeli side, and the Israeli army did not respect approvals issued by its own government (Palestinian Water Authority, 2009).

The Palestinian position in the conflict is ineffectual due to its non-existent military and weak economy. However, the Palestinians endeavor to clarify their stand and ask donor countries and NGOs for justice. This might mobilize the international community to place pressure on the Israeli government to solve the transboundary problem based on international law. In doing so, Israel must cooperate to protect shared water resources and the environment from pollution, thus achieving environmental justice towards Palestinians and the environment. Figure 6 shows the role of power and interest in the stakeholders’ engagements.
Figure 6. Engagement towards stakeholders

The position of the donor countries is shown in their understanding of the conflict and trying to use their political and economic power to fund wastewater projects and coordinate joint meetings between the two parties to discuss the problem and find the best solution.

The position of local and international NGOs regarding the conflict is based on international environmental law and on the technical issues. The NGOs act as catalysts by understanding the conflict and the position of each party. NGO development projects in water and sanitation infrastructure advances communities and protects the environment and water sources from pollution. Table 1 summarizes the conflict analysis.
Table 1. Stakeholder’s Matrix

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Role</th>
<th>What’s at stake</th>
<th>Threat/ cooperation potential*</th>
<th>Response to the conflict</th>
<th>Engagement toward party?</th>
<th>Relation to other stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Israel</td>
<td>Downstream</td>
<td>Political interest</td>
<td>H. T &amp; L. C</td>
<td>Suppression</td>
<td>H. power L. interest</td>
<td>Dormant</td>
</tr>
<tr>
<td>Palestine</td>
<td>Upstream</td>
<td>Rights &amp; ownership</td>
<td>L. T &amp; H. C</td>
<td>Management and promotion</td>
<td>L. power H. interest</td>
<td>Dependent</td>
</tr>
<tr>
<td>NGO*</td>
<td>Support</td>
<td>Interest</td>
<td>H. cooperation</td>
<td>Acceptance</td>
<td>M. interest</td>
<td>Discretionary</td>
</tr>
<tr>
<td>Donors**</td>
<td>Support</td>
<td>Interest</td>
<td>H. cooperation</td>
<td>Acceptance</td>
<td>M. interest</td>
<td>Discretionary</td>
</tr>
</tbody>
</table>

- H: High, L: Low, M: Medium, P: Potential, T: Threat, C: Cooperation

- Acceptance: Recognize a conflict, but accept whatever solution emerges or is imposed.

- Management: Acknowledge a dispute and act to control its impact

- Promotion: Parties with a serious grievance and little power may feel they need to agitate to get their problem heard.

- Suppression: Powerful parties may use their influence to deny a problem and prevent a grievance from surfacing

* Non-governmental organizations (NGO) (The main international NGOs: Friends of Earth, Oxfam, Care, Anera, B’tselem, etc.).

** Donors-Funding agencies (The main wastewater projects donors in Palestine: Germany-KFW, US-USAID, France-AFD, EU, Japan-Jica, et
2.6 Conflict Management and Resolution

Conflict management and resolution are tools that can be used to induce the parties to open up and be aware of each other’s interests and positions in the conflict itself. Management mechanisms can reduce potential conflicts by considering different perspectives and interests to reveal new management options and win-win solutions. Figure 7 below shows the negotiation map which is one of the resolution tools. A negotiation plan consists of three stages. (1) The first stage is data collection for the purpose of understanding the reality of the conflict. This stage is conducted by research centers and NGOs that are considered neutral in describing the reality. This is named as the fact-finding stage. (2) The second stage is called the mediation stage. This stage is characterized by identifying the requirements and conditions of all the involved parties in order to facilitate the development of solutions in the negotiation scenarios. On the one hand, the Israeli side calls for environmental protection by imposing high specifications and standards on the Palestinian side. On the other hand, the Palestinian side supports the protection of the environment, but within the acceptable international specifications and standards that match the Palestinian economic capacity. Whereas the donor countries, NGOs, and research centers working in the region are seeking to push the peace process and protect the environment from pollution. (3) The last stage is the negotiation stage that is intended to meet the requirements of all parties, which allows the Palestinian side to build wastewater treatment plants within the borders of the West Bank and verify the degree of processing within the international standards. However, in the cases where the treated wastewater crosses the Israeli border, then it must be within the Israeli specifications.
Figure 7. Negotiation strategic map
2.7 Conclusions

The conflict between Israel and Palestine regarding the management of transboundary wastewater is in fact not just a conflict about polluted runoff, but it is an unbalanced fight over water sources because wastewater is a major component of integrated water management. Treated wastewater can be considered as a water resource that can preserve and expand the available water resources and provide an alternative unconventional resource to meet diverse water needs while also providing protection of aquatic ecosystems. If wastewater is treated, it will then reduce the dependency on freshwater, reduce the need for water control structures (dams and reservoirs), and maintain a healthy ecosystem via improved water and wastewater management.

The conflict analysis between Israel and Palestine regarding transboundary pollution should not be limited to the “polluter pays” principle, which is based on costs of removing the pollution because wastewater is a resource and has economic, social, and environmental values after treatment. Future negotiations that aim at resolving the transboundary wastewater conflict should consider the actual economic, environmental, and social values caused by the pollution. The compensation value for the water pollution source should take into account the economic benefits of treated effluent reuse/non-use and long-term benefits such as the entry of this source in the water balance of the ecosystem.

In the environmental conflict, Israel is the stronger side in terms of land and natural resources control. Thus, it has the ability to impose its own terms on the Palestinians. If Israel’s water law aims at protecting the aquatic environment from pollution caused by Palestinian transboundary wastewater, then Israel should cooperate with donor countries and NGOs to find the best
solutions to solve the problem depending on a cooperation principle. If it is agreed that the conflict is an environmental struggle rather than political conflict, the donor countries have pledged to provide any needed funds to solve the problem, and the civil institutions are willing to provide technical assistance for the Palestinian party. The two parties, Israel and Palestine, should cooperate by granting the necessary construction permits for sewage projects and revising the high design standards. This will guarantee the sustainable operation of sewage infrastructures. Stringent by-laws and compliance with environmental standards will provide a guarantee for environmental justice and fair implementation.

The Palestinian side is the weaker party in the conflict and has the responsibility to prevent wastewater pollution in its regions after the stronger party provides appropriate conditions. This includes removing all technical and military obstacles, using the principle of cooperation, and stopping the principle of unilateral actions. The weaker side should build an effective, efficient sanitation institutional system in order to build trust and cooperation with the stronger side. The Palestinian side should invest in research to develop the sanitation sector and try to get best technical specifications that are compatible with the Palestinian environment.

The transboundary wastewater conflict between the two parties consists of three technical obstacles. (1) The first element is the stronger party attempts to impose high design criteria and effluent quality standards upon the weaker party for the establishment of sanitation facilities, in areas which do not commensurate with technical and economic potentials. (2) The second element is the restrictions imposed upon Palestinians which prevent the discharge of treated effluent into the seasonal valleys, which means an increase in the capital and running costs of sewage systems on the weaker party. (3) The third element is the definition of high sensitivity
areas for pollution because this element can lead to the relocation of proposed wastewater treatment plants in other less sensitive zones.

Donor countries and NGOs have a responsibility to foster a convergence of views between the opposing parties. Allocating funds for the establishment of wastewater treatment facilities in the weaker party’s regions leads to stem the flow of pollution into the stronger party’s regions and helps advance treated water as an additional water resource. The NGOs and donors parties also need to aid in establishing the principle of cooperation between the two sides for the purpose of making them equal parties in technical capabilities and infrastructure.
Chapter 3

Financial Challenges for Transboundary Wastewater Management from Palestinian Territories (West Bank) to Israel

Abstract

Wastewater collected from rural cities in the West Bank is being discharged to wadis (valleys) with no treatment due to the lack of a sufficient sewerage system. Wastewater runs downstream to Israel where it is treated at the expense of Palestinians. The treated effluent reuse is then used for irrigation in Israel.

The goal of this paper is to study the transboundary wastewater flow in the course of Wadi Zomer from the West Bank to Israel and to compare the benefits and costs of treating the wastewater generated in the West Bank via treating the same in Israel.

The annual quantity of wastewater flow to Israel in the course of the wadis is 11 MCM after a preliminary natural treatment; therefore, the effluent wastewater flowing down to Israel is not classified as high strength wastewater.

It would benefit Palestinians if they treated the generated wastewater in wastewater treatment plants constructed in the West Bank instead of discharging it through wadis to Israel. If all transboundary wastewater is treated in the West Bank, this will increase the available water for irrigation by 12%.

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2 This chapter was published in the International Journal of Engineering and Innovative Technology (IJEIT) Volume 3, Issue 10, April 2014
3.1 Introduction

The West Bank (WB) area suffers from limited water resources and bad wastewater systems. Only 31% of the population in the WB is connected to public sewerage systems while the remaining per cent depend on septic tanks (The World Bank, 2009). However, 70% of the households in urban cities are connected to the sewerage systems. Meanwhile, most of the rural and semi-rural communities (about 60% of the population in the WB) suffer from the lack of sewerage systems (PCBS, 2007).

Wastewater generated in the rural areas flow in different wadis with no treatment because of the inadequate number of wastewater treatment plants and poor sewerage system in the West Bank (Cohen et al., 2008). Wastewater runs to Israel, where it is treated and reused. Israel deducts the cost of treating the wastewater from Palestinians’ tax money and make use of the treated effluent in irrigation (Al-Sa’ed, 2010). Israel deducts the cost of the treatment and sends the final bill to the Palestinians with no prior agreement or approval. Palestinian officials claim that the invoices shared with them by the Israeli parties are not reliable (Interview with ‘Adel Yassin, 2012 ). The Israeli environmental officer in the West Bank rejects this claim and states that Israel is completely committed to solving the problem of the transboundary wastewater issue. He also believes that the price paid by Palestinians for the treatment of their wastewater flow is fair and abides by common practices in similar cases (Benny, 2013).

The purpose of this paper is to compare the cost and benefits of treating the main wastewater transboundary flows in Israel versus being treated in the West Bank. The set objectives for this study are as follows:
To measure the transboundary wastewater flows in Wadi Zomer in the West Bank to Israel.

To characterize the quality of the wastewater flow in Wadi Zomer.

To run a preliminary comparison between the cost and the benefits for the different scenarios including the scenario of no action.

It is projected that 25 million cubic meters of untreated wastewater is disposed into the environment from more than 350 locations across the West Bank. Israel built many sewage treatments plants to treat the flows crossing the Green Line from the West Bank and makes use of the treated effluent in irrigation and artificial recharge of the ground aquifers (Al-Sa’ed and Al-Hindi, 2010).

There are 15 tributaries crossing the Green Line between Israel, the West Bank, and Gaza district. Twelve of them flow towards the Mediterranean Sea in the west while the other three flow towards the Dead Sea and Jordan River in the east. These main transboundary streams are: Wadi Moqatta, Wadi Al Zomer, Wadi Al Zhoor (Wadi Salman), Wadi Soureek (Wadi Aljeeb), Wadi Beit Jala, and Wadi Samen.

The focus of this paper is Wadi Al Zomer as one of the main transboundary watercourses that transport the wastewater generated in the West Bank to Israel to be treated inside the Green Line.

3.2 Transboundary Wastewater Stream Effects on the Catchment Area

Transboundary wastewater flows affect the surrounding Israeli and local Palestinian communities in a negative way. These flows contaminate the groundwater resources, considered the main water source for both Israelis and the Palestinians. The worse scenario is when the wastewater is disposed directly on outcrops of the groundwater aquifers. The untreated
wastewater with strong pollutants mixes directly in a short time with groundwater, resulting in direct contamination of the groundwater resources (Lior et al., 2007).

The local population suffers due to wastewater flows running within their communities. Wastewater flows generate malodorous smells, increased insect populations and have a negative effect on the health of people living in these communities (Fischhendler, 2007).

Israel constructed many sewage treatment plants to treat the wastewater flow running from the West Bank, benefitting from the reuse of treated effluent in irrigation and the artificial recharge of groundwater. Israel paid for the capital cost and the operational and maintenance costs for these wastewater treatment plants (WWTPs) from the tax money collected from Palestinians.

The total amount deducted from the Palestinian's due tax money for this purpose up to 2009 is more than 200 million NIS (Alon et al., 2010). There is no clear agreement between the Israeli and Palestinian parties regarding the cost of Palestinian wastewater treatment in Israel, but the Israeli party bills Palestinians for these costs. Upon review of the invoices received by the Palestinian Water Authority (PWA) from Israel the following was noted. Israel generally sends the bills to cover the cost of treating wastewater flows during a certain period for a certain watercourse with no supporting details for the deducted money. Some of these bills cover only the quantity of the treated wastewater while other invoices cover only the cost with no mention of the treated quantity. In some cases and according to the request of the Palestinian party, Israel sends details in order to account for the money deducted. Sometimes they use estimated wastewater quantities and sometimes they use measured quantities. For example, wastewater quantity running along Wadi Beit Jala was estimated based on the measurements conducted on the pipeline in the year 2006 by Israel. Meanwhile, the amount of wastewater flow from Birnabal
Al Jeeb and Al Ram in Wadi sourik was predicted. In this example, 100 liters per capita was adopted as the daily generated wastewater flow, which is not a realistic assumption in comparison with the available water for use in the West Bank. Palestinians are not part of the measurement or the estimation process for the quantity and quality of the wastewater. Table 2 shows different rates for treating one cubic meter of the wastewater in Israel. In 2010, the following rates were adopted to calculate the cost to be deducted from Palestinian funding in addition to 16% value added tax:

<table>
<thead>
<tr>
<th>Catchment Area</th>
<th>US (CENTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beit Jala and part of Bethlehem that discharges in Wadi Beit Jala</td>
<td>48</td>
</tr>
<tr>
<td>Birnabala, Al Jeeb, and Al Ram that discharges in Wadi Surik</td>
<td>55</td>
</tr>
<tr>
<td>Jenin area that discharges in Wadi Al Muqatta</td>
<td>25</td>
</tr>
</tbody>
</table>

Any wastewater project to be implemented in the Palestinian Authority area must pass through a complicated process. This is for both the implementation of wastewater collection systems and the construction of WWTPs. In order to get a license for implementation, any wastewater project in the Palestinian areas must comply with several requirements prior to the implementation.

The Joint water Committee Approval (JWC) was established according to article 40 of Oslo II Interim agreement and is responsible for managing the water and wastewater services in West Bank and Gaza District. All water and wastewater projects located in area A, B, or C in the Palestinian area should apply for the approval of this committee (B’Tselem, 2009). The Israeli members of this committee delay approval by placing conditions and asking for studies.
It is generally recommended that the wastewater treatment plants should be located away from the populated areas to mitigate the environmental and health impacts. Most of the low populated areas lie in area C. For any project to be constructed in area C, the approval from the “Israeli Civil Administration” is required. This is a very long and problematic process and it is preferred to avoid this by locating the WWTPs outside area C. Feasibility studies conducted for wastewater projects in the West Bank take this into consideration when selecting the WWTPs locations.

On the basis of the Memorandum of Understanding signed by the Israeli and Palestinian in December 2003 (Peace Process, 1995), the principle guidelines for the treated effluent and technical concepts for wastewater projects include the maximum values for BOD as 20 mg/liter and for TSS as 30 mg/liter for preliminary treatment. If the treated effluent will be used for irrigation in high hydrologically sensitive areas or to be drained to wadis or streams, then a secondary treatment for the wastewater is required and the maximum value for BOD is 10 mg/liter and for TSS is 10 mg/ltr. Achieving these standards mean higher capital and operational costs, which is difficult for Palestinians to afford, threatening the sustainability of these projects.

Based on the Palestinian Authority’s stance regarding the non-legitimacy of the Israeli settlement in the West Bank, the Palestinian Water Authority does not wish to connect the wastewater flows from these settlements. They consider that such a connection would mean that the PWA is accepting the right of these settlements to exist on Palestinian land. Further, when there is an Israeli settlement near a recommended site of the Palestinian WWTP (for example, Salfit WWTP), Israel will delay approval and complicate the process (JWC, 2003).
3.5 Wadi Al Zomer Transboundary Stream Field Study

3.5.1 Study Area

Wastewater in Wadi Al Zomer is collected from West Nablus, Ein Beit Alma Camp, and some adjacent communities which are partially served by the sewage network (Beit Iba, Deir Sharaf, Zawata, and Anabta). Wastewater from Tulkarem, Tulkarem camp, and Nur Shams Camp is collected, partially treated in the Tulkarem ponds, and then flows towards the Green Line. Wastewater from Nablus and the Tulkarem areas is treated inside the Green Line in Yad Hanna WWTP.

3.5.2 Measuring Points

Three points of measurements were identified in the Wadi Al Zomer area. The first point was located upstream of Wadi Al Zomer near Beit Eba, the second point was located at the end of Wadi AL Zomer in Tulkarem, and the third point was located at the outlet of the Tulkarem lagoons. Table 3 below lists the measurement points and the wastewater source at these points.

Table 3: Measuring Points and Source of Wastewater Flow in the Targeted Stream

<table>
<thead>
<tr>
<th>Stream (Wadi)</th>
<th>Measuring Points</th>
<th>Wastewater Source Discharge</th>
<th>Coordinates of Measuring Points</th>
<th>Received Israeli WWTP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wadi Al-Zomar</td>
<td>Beginning of Wadi Al-Zomar/Beit Eba area</td>
<td>West Nablus</td>
<td>167,835 184,222</td>
<td>Yad Hanna WWTP</td>
</tr>
<tr>
<td></td>
<td>End of Wadi Al-Zomar/Tulkarem area</td>
<td>West Nablus, Ein Beit Alma Camp, and some adjacent communities</td>
<td>153,015 192,298</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Outlet of Tulkarem Ponds</td>
<td>Tulkarem and camp and Nur Shams Camp</td>
<td>151,832 191,326</td>
<td></td>
</tr>
</tbody>
</table>

(PWA, Understanding and Analyzing the Current Israeli Wastewater Practices for Transboundary Wastewater Management from Palestinian, 2012)
3.6 Methodology

The researcher conducted six monthly field visits to the wadi. The field visits were in June, July, October, November, January, and February to cover different seasons. The work included two main activities:

1. Flow measurements: This includes site measurements, time of measurements, equipment, methods for calculating the dimensions of the channel, and methods of calculating the amount of flow.

2. Sampling: This process includes sampling site, period, equipment used in flow measurement, and the size of the sample.

3.6.1 Flow Measurements

The cross section and the dimensions of each measuring point were selected according to the circumstances of the wadi path. Table 4 shows the geometric cross sections for each measuring point at the wadi.

<table>
<thead>
<tr>
<th>Name</th>
<th>Cross Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wadi AL-Zomar, Nablus</td>
<td>Parabolic</td>
</tr>
<tr>
<td>Wadi AL-Zomar,Tulkarem</td>
<td>Parabolic</td>
</tr>
<tr>
<td>Tulkarem WWTP</td>
<td>Circular</td>
</tr>
</tbody>
</table>

(PWA, 2012)
Site visits were conducted on the first day of the month. The period of the flow measurement started at 8 am and ended at 5 pm. The calculation mechanism of the flow quantity was based on two items which were:

1. The position of the wadi path and its dimensions.
2. The flow meter equipment that was used to measure the velocity of the wastewater flow during a specified period with specific dimensions.

### 3.6.2 Sampling

The sampling process was conducted two days per month during the period of the study. The average number of field visits was six.

Two liters of wastewater were collected and kept in plastic bottles which were printed with the time of the site visit, wadi name, and the sample symbol. The samples were collected with a specialized tool (a stick ending with a bowl) made for the purpose of this study. The samples were delivered to laboratory for testing.

### 3.7 Final Results of Quantity and Quality

The calculated total amount of discharged wastewater in the targeted streams was 11 MCM/year. Table 5 shows the final results of the flow measurements. The average daily flow was calculated based on one instantaneous measurement in the day.
Table 5: Final Results of Flow Measurements at Wadi Al-Zomer District

<table>
<thead>
<tr>
<th>Date</th>
<th>Q1(m³/day)</th>
<th>Q1(m³/day)</th>
<th>Q1(m³/day)</th>
<th>Q1(m³/day)</th>
<th>Q1(m³/day)</th>
<th>Q1(m³/day)</th>
<th>Qavg. (m³/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning of Wadi Al-Zomer/Nablus</td>
<td>10,981</td>
<td>11,543</td>
<td>11,733</td>
<td>11,880</td>
<td>15,264</td>
<td>17,453</td>
<td><strong>13,142</strong></td>
</tr>
<tr>
<td>End of Wadi Al-Zomer/Tulkarem</td>
<td>9,322</td>
<td>8,778</td>
<td>1,005</td>
<td>8,562</td>
<td>10,368</td>
<td>11,808</td>
<td><strong>9,807</strong></td>
</tr>
<tr>
<td>Tulkarem WWTP</td>
<td>4,320</td>
<td>4,276</td>
<td>3,888</td>
<td>3,524</td>
<td>3,637</td>
<td>3,628</td>
<td><strong>3,881</strong></td>
</tr>
</tbody>
</table>

(PWA, 2012)

The difference in wastewater flow quantities in the wadi is associated with the following factors:

- **Weather temperature:** During the hot weather the wastewater generated increases due to increased water consumption. However, this factor is linked to the availability of water.

- **Rain period:** Wet weather flow in streams is higher than dry weather flow. The increased wastewater during wet weather at the measuring points is affected by different aspects:
  - Intensity of rainfall and rainwater runoff
  - Location of the measuring point if it is located at the end of a closed system (wastewater network) or in an open system (wadi). The effect of rainfall on open systems is much higher as it is affected by the rain runoff from secondary tributaries.
• Time of measurement: Generated wastewater varies throughout the day due to fact that the instantaneous measure and the measuring times were not the same during these months. Therefore, the calculated average daily flow was affected.

3.8 Result of Quality Analysis

The available data for wastewater quality in the West Bank demonstrate BOD values from 400 mg/ltr to 1400 mg/ltr with an average of about 600 mg/l (Isaac, Qumsieh and Owewi, 1997). This high level of BOD is due to the low water consumption in Palestine compared with developed countries (Haddad, Mizyed, and Abdulah, 2009). This is compatible with the measured values of BOD in Wadi AL Zomer which is less than 400 mg/ltr. This is classified as medium strong wastewater because of the treatment by natural aeration before being discharged to the wadi upstream of the measuring points which results in the degradation of organic matter. According to the Food and Agriculture Organization (FAO, 1992), this means that wastewater reaching Israel is not classified as strong wastewater. Table 6 below demonstrates the classification of the wastewater run in Wadi AL Zomer in terms of organic concentration (FAO, 1992). shows the classification of the wastewater at the measuring points in terms of organic concentration.

Table 6: Classification of Wastewater in Terms of Organic Concentration

<table>
<thead>
<tr>
<th>Location</th>
<th>Avg. BOD (mg/l)</th>
<th>Avg. COD (mg/l)</th>
<th>Classification*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wadi Al Zomer, Tulkarem</td>
<td>282.4</td>
<td>502.7</td>
<td>Medium</td>
</tr>
</tbody>
</table>

(PWA, 2012)

* Typical categories of raw wastewater in terms of contamination degree
**BOD:COD Ratio:** This ratio reflects the biodegradability of organic matter in wastewater; this ratio is zero if organic matter is not biodegradable and one if all is easily biodegradable. The typical BOD:COD ratio for municipal wastewater is 0.5 (Lawrence, Yung-Tse, and Nazih, 2000).
Table 8: Final Results of Wastewater Characteristics at the Targeted Wadis

shows the BOD:COD ratios for wastewater at the measuring points. The average values of the BOD:COD ratios are around the typical ratio of municipal wastewater.

Table 7: BOD: COD Ratio

<table>
<thead>
<tr>
<th>Location</th>
<th>BOD: COD Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Wadi Al-Zomar Tulkarem</td>
<td>0.53</td>
</tr>
</tbody>
</table>
Table 8: Final Results of Wastewater Characteristics at the Targeted Wadis

<table>
<thead>
<tr>
<th>Location</th>
<th>Date of Sampling</th>
<th>pH</th>
<th>BOD (mg/l)</th>
<th>COD (mg/l)</th>
<th>TSS (mg/l)</th>
<th>NH4 (mg/l)</th>
<th>PO4 (mg/l)</th>
<th>Cl (mg/l)</th>
<th>B (mg/l)</th>
<th>TDS (mg/l)</th>
<th>DO (%)</th>
<th>Temp. C°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wadi Al-Zomer/Tulkarem</td>
<td>Average</td>
<td>7.6</td>
<td>282</td>
<td>503</td>
<td>3567</td>
<td>82</td>
<td>1.5</td>
<td>775</td>
<td>6.4</td>
<td>1737</td>
<td>1.4</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Min.</td>
<td>7.0</td>
<td>109</td>
<td>240</td>
<td>1268</td>
<td>65</td>
<td>0.2</td>
<td>300</td>
<td>1.77</td>
<td>876</td>
<td>0.8</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Max.</td>
<td>7.9</td>
<td>470</td>
<td>720</td>
<td>9510</td>
<td>94</td>
<td>5.5</td>
<td>1200</td>
<td>68.4</td>
<td>2510</td>
<td>2.4</td>
<td>21</td>
</tr>
</tbody>
</table>

(PWA, 2012)
3.9 Cost Benefit Analysis

This part of the paper aims to conduct a cost benefit analysis (CBA) for the different alternatives which are:

- **No Action Alternative**: Keep the current situation as it is with the wastewater discharged to wadis and flow towards Israel to be treated there at the cost of the Palestinians.

- **Action Alternative**: Construct WWTPs inside the West Bank to treat and reuse the treated effluent.

**Comparison between Costs and Benefits**

This part of the paper discusses a preliminary comparison between the costs and benefits for the different alternatives.

1. **Capital Cost**

Capital cost is the cost of construction of the main trunk lines to transport the generated wastewater to the location of the WWTP. It also includes the costs of all of the elements in the WWTP, including the process and operational buildings in addition to the cost of the conveyance systems for the treated effluent to the identified agricultural areas or wadis.

The construction of WWTPs inside Israel is already a Palestinian expense in the current situation. Therefore, there will be no difference between the two alternatives in terms of capital costs because in both scenarios the Palestinians pay for the WWTPs and associated construction.
2. Running Costs

Running costs are the operational and maintenance costs for the WWTPs and associated facilities. Israel adopts different rates for the cost of treating one cubic meter of wastewater.

Feasibility studies conducted for the western Nablus WWTP and Jericho WWTP calculated the cost for treating one cubic meter of wastewater as 1.8 NIS and 1.5 NIS, respectively. According to the municipality engineer, the equivalent cost for Al Bireh’s existing WWTP is 1.8 NIS. Therefore, the expected cost of the action alternative will be in the range of 1.5-1.8 NIS per cubic meter, while it is in the range of 0.97-2.12 NIS per cubic meter for the no action alternative.

Positive Impacts

Constructing WWTPS in the West Bank will have positive impacts for the Palestinians and the surrounding environment. The main impacts are summarized below:

1- Groundwater Protection

Discharging the wastewater into the existing streams will contaminate the groundwater quality. Therefore, the construction of WWTPs and the associated facilities will eliminate this factor in the deterioration of groundwater aquifers and thus improve the water quality.

2- Impact on Agricultural Sector

Treated effluent is a non-conventional source of water that could be used for agriculture. This will provide farmers with a sufficient and affordable source of irrigation water. It also contains many plant nutrition elements which will promote plant growth and increase yield. This can be beneficial for agriculture as it reduces the use (and the associated cost) of chemical fertilizers.
The targeted wastewater streams generate about 11 MCM/year of raw wastewater. If the wastewater is treated, the treated effluent is almost the same amount. Reusing the treated effluent will increase the available volume of agricultural water by 12%, where the current supply of water in West Bank through irrigation is about 89 MCM/year (Adilah, 2010).

**3- Water Management**

Using treated wastewater in irrigation will reduce pressure on the conventional water resources by reducing the demand on freshwater, so it may be used by other sectors. This unconventional water source was found to be economically feasible.

**4- Health**

By implementing wastewater treatment projects for the transboundary streams, the overall public health and hygiene conditions will be improved. Illnesses related to water contamination will be dramatically controlled.

**5- Socio-Economic Settings**

Many residents and farmers are unemployed due to the restrictions and difficulties imposed by the current political situation, increasing water shortages, and difficulty in reclamation of land for agribusinesses. Providing treated wastewater for agricultural purposes will be highly beneficial because it will encourage investing in agricultural businesses, provide job opportunities, and improve the overall quality of life of the population. New job opportunities will be created to operate and maintain the WWTP site. Additional administrative and support roles will be required which will also reduce the unemployment rate.
3.10 Conclusions and Recommendations

Error! Reference source not found. 9 provides a summary of the comparison between discharging the wastewater (the current situation) from the West Bank towards Israel (no-action alternative) and implementing WWTPs inside the Palestinian areas (action alternative).

Table 9: Comparison Summary between the Action and No-Action Alternatives

<table>
<thead>
<tr>
<th>Item</th>
<th>No-Action Alternative</th>
<th>Action Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment Cost</td>
<td>Palestinians pay the investment cost</td>
<td>Palestinians pay the investment cost</td>
</tr>
<tr>
<td>Running Cost</td>
<td>0.97-2.12 NIS/m³</td>
<td>1.5-1.8 NIS/m³</td>
</tr>
<tr>
<td>Impact on Groundwater</td>
<td>Groundwater quality will be degraded</td>
<td>Groundwater protection will be enhanced and its quality improved</td>
</tr>
<tr>
<td>Impact on Agricultural Sector</td>
<td>The agricultural sector will remain the same</td>
<td>Providing a new source of water for agriculture will enhance the agricultural sector in Palestine</td>
</tr>
<tr>
<td>Water Management</td>
<td>The water system will remain the same</td>
<td>The share of water available for the domestic sector will be increased by reallocation of water shares between different sectors (domestic, agricultural, and industrial) since the treated wastewater will contribute in the agricultural water share.</td>
</tr>
<tr>
<td>Health</td>
<td>Negative impacts on public health</td>
<td>The overall public health and hygiene conditions will be improved</td>
</tr>
<tr>
<td>Socio-Economic Settings</td>
<td>Socio-economic conditions will remain the same</td>
<td>Investment in agricultural businesses encouraged, job opportunities increased, and the overall quality of life of the population improved.</td>
</tr>
</tbody>
</table>

(PWA, 2012)
Error! Reference source not found. 9 shows that the investment and operational costs for the wastewater systems are almost the same in the both alternatives. In the current situation (no-action alternative), there are no benefits for the Palestinian and there are many negative impacts, while in the action alternative, the Palestinians will benefit from the treated wastewater and avoid the negative impacts of the no-action alternative.

The following are the main recommendation for this study:

- Palestinians benefit if they treat the wastewater instead of discharging it into the wadis to be treated in Israel as they can reuse the treated wastewater in the agriculture sector.

- Wastewater that is treated and reused from the targeted streams will increase the available volume for agricultural water by 12%.

- A detailed CBA and feasibility study for each wadi to study more alternatives and inspect the best specific solution for each wadi in terms of WWTP location, treatment technology, reuse area, and irrigated crops is needed.
Chapter 4
Simulation of Transboundary Wastewater Resource Management Scenarios in the Wadi Zomer Watershed, Using a WEAP Model

Abstract

Water resource shortages are always a challenge for Middle Eastern countries in general and for the Palestinian Authority in particular. For over 20 years in Palestine, political factors and a lack of control over water resources have exacerbated the water problem there, seriously affecting water resources in terms of quality and quantity. This research presents one of the applications of the Water Assessment and Planning (WEAP) model in the Nablus and Tulkarem watershed. The model was applied in evaluating and analyzing the existing balance and the role of treated wastewater and anticipates future scenarios for the management of water resources, taking into account the policies and various factors that may affect the demand and impact of treated wastewater on the water budget until 2035.

The results showed that the amount of treated wastewater in the study area will reach 16 MCM by 2035. The agricultural sector needs 17 MCM and currently only 2.8 MCM are available from artesian wells. The results also showed that one of the reasons for not using treated wastewater is a lack of experience in the planning and selection of wastewater treatment plant sites and the capacity to match these with agricultural land that could reuse the treated wastewater. Demand management and improvements in living standards are the prerequisites necessary for the proper management of available resources. The results confirmed that the WEAP program provides a

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3 This chapter was published in International Journal of Basic and Applied Sciences, 4 (1) (2015) 27-35
solid foundation to assist planners in developing recommendations for the management of water resources in the future, through the detection of hot spots on which to work.

4.1 Introduction

The Arab world occupies 10% of the earth’s land surface and comprises 5% of its population. However, it owns less than 0.5% of the renewable fresh water resources in the world (Khouri, 2007). Currently, Arab water consumption per capita is less than 1,000 cubic meters per year and is expected to fall to 464 m³ per year in 2025. Most of the water in the Arab world originates from outside the region with eight non-Arab countries controlling 85% of Arab water resources (Emirate Center for Strategic Studies and Research, 2009).

The water situation in the occupied Palestinian territories (oPt) is no better or worse than that encountered in the other Arab countries. The average daily water consumption of Palestinian citizens is 60 liters, which is much lower than the rates set by the World Health Organization as the minimum consumption of 100 liters of water per capita per day (Hassan, 2012).

In developing countries, 90% of the sewage flows untreated into rivers, valleys, lakes, coastal areas, and sometimes across political boundaries and threatens the health, food security, and access to safe drinking water and bathing water of its citizens (Corcoran, 2010). In the West Bank, wastewater flows into valleys in two directions, to the west and the north-east and towards the east. The West Bank generates about 70 million m³ of domestic wastewater annually, 65% of which is produced in the western and the north-eastern basins which flow both towards Israel and to the eastern direction (Aya, 2007). That means 45 million m³ of sewage are produced annually in the western and the north-eastern regions of the West Bank, 17 million m³ of which is collected by sewage networks and disposed of into streams and valleys running towards Israel,
and the remaining 28 million m$^3$ are disposed of in cesspits. This paper focuses on the Wadi Zomer catchment area, which produces about 6 million m$^3$ of wastewater annually, or about 35% of the wastewater that crosses into Israel from the West Bank. (Yaqob, 2012).

The quality of the main source of water used in Israel and the Palestinian Territories, the mountain aquifer, is in acute danger. The main receiving stream bed in the area is Wadi Zomer. This wadi (valley) is used as a conduit for draining sewage from the towns of Nablus, Anabta, parts of Tulkarem, and the villages located on the banks of the wadi. A rough estimate of half of the sewage load generated between Nablus and Tulkarem infiltrates into the groundwater. In addition to the wastewater discharged into the wadi, a large portion of domestic sewage, from houses not connected to the central sewerage system, is contained in cesspits (Tal et al., 2007).

The Palestinian Authority faces a huge challenge, not only in meeting the water demand of the municipal, industrial, and irrigation sectors, but also in providing water to meet the increasing needs for these sectors in the future. It is becoming clear that developing new water sources will not be enough to overcome these challenges; the solution must be tied to a wiser use of the current sources of water through water demand management measures, water reuse, and maintenance of good water quality.

This paper presents one application of the WEAP model in the Wadi Al Zomer watershed and considers the untreated wastewater in the valley as a river. The applied model is used to evaluate and analyze the remaining balance and expected future scenarios for wastewater management, taking into account factors that may affect this demand until 2030, in order to ensure future sufficiency and sustainability of the available water in terms quantity and quality to meet different long-term demands.
4.2 Location

The Wadi Zomer catchment area is located in the northern part of the West Bank. It is part of the catchment area representing the largest groundwater source in the region, the mountain aquifer. This area has some of the highest precipitation rates in the West Bank (average 600-700mm/year). However, it is characterized by a growing scarcity of water (Tal et al., 2010).

The upper area of the Wadi Zomer catchment is Nablus and its surrounding villages while the lower area of the catchment is represented by the city of Tulkarem and its surrounding villages (Tal et al., 2007). The two main communities are shown in Figure 8.

Figure 8: Wadi Zomer catchment
4.2 Metrological Data

The climate in the area is Mediterranean, with moderately hot summers and moderately warm winters. The mean annual maximum temperature is 22.3 ºC. The average rainfall per annum amounts to 642 mm. The potential evapotranspiration (PET) amounts to about 100mm during the months May to October. From December to March the PET is less than 50mm, whereas April and November are transition months, with a PET of about 75mm (Tal et al., 2007).

4.2.1 Topography and Geological Formation

The study area lies on the western slopes of the West Bank, with plain areas to the west and mountainous terrain to the east. The elevation ranges from 50m a.s.l. to 450m a.s.l. Wadi Zomer stretches from the Green Line to Deir Sharef. The bottom of the valley is at an elevation of between 50m a.s.l. and 200m a.s.l. Topographically the syncline is asymmetrical, with a gently dipping western limb and a steep eastern one.

4.2.2 Water Resources System

The main source of domestic water in the West Bank derives from the shallow and deep water bearing formations of the mountain aquifer. This aquifer is commonly considered in three parts named the Western, North-Eastern, and Eastern Basins. The Tulkarem district lies nearly entirely in the Western basin, whereas the Nablus district is located in all three basins.

Wadis have a typical temporary runoff pattern, with surface runoff only during the winter season (from the months of November to March). However, Wadi Zomer shows permanent runoff throughout the year, with domestic and industrial wastewater, mainly from Nablus in the upper catchment area and from Anabta and Tulkarem in the lower catchment area, during the dry season (PWA, 2012).
The total water consumption in the project area amounted to about 3 million m³ in 2006. Average water losses in the range of 40% result in water production of more than 4.6 million m³. Based on the metered water consumption and the population figures provided by the Palestinian Central Bureau of Statistics (PCBS), the average per capita water consumption is 68.8 l/c/d. (PCBS, 2014).

4.2.3 Agricultural Area Land Use

Nablus West WWTP’s potential effluent irrigation areas can be found nearby the site. The first area of interest stretches along the WWTP site itself, covering an area of about 35 ha. Technically, being situated directly in the plain of the valley, the application of effluent would be relatively uncomplicated.

Wider and more extended agricultural areas are located near the village of Sabastia. However, from a geographical point of view, before reaching this area the hill dividing both plains has to be crossed. This is an area of approximately 250 ha.

The available 285 ha (35 plus 250 ha) of land can be served in its entirety once the WWTP has been commissioned. However, by 2020 additional areas of 100-200 ha will be needed to absorb all the effluent generated.

Currently, all areas in question are rain-fed; no irrigation infrastructure exists. However, the potential irrigation areas are located at higher elevations than the treatment plant sites, so would require effluent pumping (Haddad, 2012).
From Nablus West WWTP the anticipated volume of treated wastewater at start up is 11,472 m$^3$ per day in the year 2013. By 2035 the WEAP model estimated that 27,377 m$^3$ of effluent per day will be generated.

Considering the effluent generated and the proposed crop composition, the potential irrigation areas identified might be fully served by these flow rates. However, as already indicated, for Nablus West WWTP additional area is required in the future. As no other freshwater resources are available, effluent will be the only source of irrigation water. This will require the development of a proper irrigation water and fertilizer management system.

### 4.2.4 Crop Composition

The composition of future cropping has been estimated on the basis of anticipated profitability, market needs and the experience of farmers in the region. According to national wastewater effluent standards, regulations, and legal restrictions or recommendations by the Ministry of Agriculture (MOA), vegetables and olives were excluded from the future cropping pattern used in the model (PWA, 2014). The proposed main crops to be irrigated with effluent are barley, alfalfa, Sudan grass, and stone fruits, such as almonds.

### 4.3 Water Evaluation and Planning System

The Water Evaluation and Planning (WEAP) software package was selected for the purpose of this study. The WEAP is a practical tool for water resource planning, as it considers both water supply and demand issues in addition to water quality and ecosystem preservation, as expected of an integrated approach to basin management (SEI, 2007). The model is semi-theoretical and needs calibration and verification (Abridamchi, Alizadeh, and Tajrishy, 2007).
The WEAP is a tool used to examine alternative water development and management strategies (SEI, WEAP user’s guide, 2005). The model simulates water system operations within a river system, using basic water accounting principles based on a user-defined time step; it computes water mass balance for every node and link in the system for the simulation period (Yilmaz, Nilgun, and Harmancioglu, 2010). The simulation allows the prediction and evaluation of “what if” scenarios and water policies, such as water conservation programs, demand projections, hydrologic changes, new infrastructure, and changes in allocations or operations (Mutiga et al., 2010).

For the purpose of this paper, the WEAP model is adapted to simulate the wastewater situation in the Wadi Zomer catchment, where wastewater reuse represents an important possible management option.

### 4.3.1 Wadi Zomer Watersheds Modeling

Running the WEAP program requires the input of a large volume of data, for every element in the network. The data structure and level of detail used can easily be customized to meet the requirements of a particular analysis and to reflect the limits imposed when data is limited (Yates et al., 2005). To set up the model, monthly time steps were used in the hydrologic simulation, for the following reasons: (1) compatibility with significant hydrologic process time periods and (2) the existence of the data in a monthly framework. The WEAP model representation of the Wadi Zomer watershed is shown by Figure 9.

In the WEAP model, each main community group was assumed to be a demand node, supplied by water and returns the wastewater to the nearby wadi. This wadi is known locally as Wadi Zomer and it flows continuously, forming a river of wastewater from nearby communities.
Demand site priority, which tells the WEAP the order in which water should be allocated to different users, is an important input. Domestic demands were given priority over agricultural demands, whenever domestic and agricultural demands competed for the same water resource.

### 4.3.2 Model Calibration and Validation

The goal of the model calibration is to adjust the parameters so that the model solutions fit the observations in an optimal fashion. Model calibration was done manually, through trial and error, seeking to minimize the root mean square error (RMSE) and to maximize the correlation coefficient, \( R \). WEAP’s watershed hydrology module approximates critical hydrologic processes making use of a few key parameters. These include: a plant/crop coefficient (\( K_c \)), which in combination with an estimation of potential evapotranspiration determines evaporative losses; a conceptual runoff resistance factor (\( RRF \)), related to factors such as leaf area index and land slope with higher \( RRF \) values representing reduced rapid surface runoff; and water-holding capacity and hydraulic conductivity parameters that determine the slower, interflow response. A
partitioning fraction (preferred flow direction) determines whether water moves horizontally or vertically.

The 2006 data was used for model calibration and the 2007 data was used for model validation. For this research, naturalized stream flows from the selected stations were compared with the results of the model.

Calibration was implemented using flow measurements that were taken in previous years. Flow data is from a report by the House of Water and Environment, and the location of flow meters is shown in Figure 9.

On the other hand, the flow measurement for the Deir Sharaf area was provided by the officer of the Deir Sharaf pilot wastewater treatment plant, which was 600 m$^3$/hr, equivalent to 14,400 m$^3$/day.

In general, effluent utilization rates did not exceed 70% of the available effluent, due to periods of zero/low demand (December to February) and the seasonal crop demand variability. In the later stages water utilization rates decreased because extra effluent was available and available land was limited (Nablus West only).

This means about 30-40% of the effluent needed to be disposed of/reused, especially in winter time. As such, we propose that effluent be discharged into adjacent wadis, at least during the initial operational phases of the WWTPs.
4.4 Management Alternatives and Scenario Analysis

4.4.1 Reference Scenario

The “current accounts” is the dataset from which the scenarios are built. Scenarios explore possible changes to the system in future years beyond the “current accounts” year. A default scenario, the “reference” or “business-as-usual” one, carries forward the current accounts data into the entire specified project period and serves as a point of comparison for the other scenarios in which changes are made to the system data. The current situation (2006) is extended to the future (2007–2030). No major changes are imposed in this scenario. The only one analyzed is a situation without the development of large irrigation systems and with MAO Transfers.

4.4.2 Other Scenarios

**Scenario 1:** Represents the current situation in which wastewater produced is not used but flows to the Israeli side to be treated and reused by Israel, with no benefit for the Palestinians.

**Scenario 2:** Represents the situation in which a WWTP is built west of Nablus and treats the wastewater produced by the western part of Nablus and the surrounding villages, represented in the model by the node “Nablus City”. The treated wastewater is used in nearby agricultural areas, represented in the model by the demand node “Nablus_Agr” (Figure 9). In contrast, the wastewater produced in the Tulkarem area is not treated and is allowed to flow to the Israeli side.

**Scenario 3:** A new WWTP constructed near Tulkarem to treat wastewater from the Tulkarem area and the treated effluent is used in Tulkarem agricultural areas represented in the model by the demand node “Tulkarem_Agr” (Figure 9).
4.5 Results

**Projection of Wastewater from Palestinian Communities**

The model shows rates of wastewater flowing, and expected to flow in the coming years, to WWTPs as follows:

Figure 10 shows the wastewater generated in the study area, which is expected to reach 14.8 million m³ per year by 2035. The WEAP model was built and calibrated based on wastewater flow rates calculated through a complex process of referring to most of the available studies between 2006 and 2014 and all actual onsite measurements in the valley. The volume of wastewater generated from the Western Nablus Province in 2035 is predicted to be about 8 million m³, which represents 54% of that produced in the entire study area.

![Figure 10. Wastewater treatment plant inflows and outflows](image-url)
Figures 11 and 12 illustrate the agricultural land needs of water in the study area, which are estimated at 17.5 MCM while the farmland in the Nablus area needs only 1.5 MCM and the Tulkarem area needs about 16 MCM annually.

Figure 11. Nablus irrigation water demand
The WEAP model was designed to include three scenarios, in order to simulate reality and find the best options that can be applied to achieve successful management and sustainability of water resources.

**Scenario 1:** Represents the current situation, in which the wastewater produced is not reused in the West Bank but flows to Israel, to be treated and reused there, without any benefit for the Palestinians.

In this scenario no WWTP will be constructed on the Palestinian side and wastewater will flow, without any treatment in the wadi, to Israel. The Palestinian side pays for the wastewater treatment costs to the Israeli side, which may amount to about 6.35 million dollars per year by 2035, taking into consideration the current price of 44 cents per cubic meter. In this scenario, Palestinian
agricultural land does not benefit from effluent reuse and will remain without an additional water source for irrigation.

Figure 13 shows that the only water source available for agriculture in the study area is fresh water from the aquifer, with an estimated capacity of 2.8 million m$^3$ per year. The estimated water deficit in this scenario is about 15 million m$^3$ annually.

![Figure 13. Water supplied to agriculture in the current situation from groundwater wells](image)

**Scenario 2:** Represents the situation in which a wastewater treatment plant is built west of Nablus to treat wastewater produced in the western part of Nablus and the surrounding villages, represented in the model by the node “Nablus City”. The treated wastewater is used in nearby agricultural areas, represented in the model by the demand node “Nablus_Agr”. In contrast, wastewater produced in the Tulkarem area is not treated and is discharged to the wadi on the Israeli side.

This scenario reflects the Palestinian Water Authority’s approved plan, which includes constructing a WWTP serving the western Nablus area, with untreated wastewater delivery lines serving the Tulkarem area running towards Israel.
Agricultural land in the Nablus area needs 1.8 MCM of water for irrigation annually while farmland in the Tulkarem area needs 15 million m³ per year.

Adopting this scenario will lead to the loss of 87% of the wastewater generated in the study area to Israel. To enable the Palestinian farmers to benefit from 72.5% (27.5% used in the only available agriculture land) of the treated water from the Nablus treatment plant, it would require the implementation of an agriculture infrastructure project for trunk carrier lines, pumps, and reservoirs.

Figure 14 shows the estimated wastewater flow rates in the valley once the Nablus WWTP is operational. The yellow line shows that 9 MCM will cross the Israeli border. Figure 15 shows that Nablus agricultural land would get 1.5 million m³ per annum of treated wastewater and that Tulkarem farmland would remain dependent on 2.8 MCM per year from groundwater.

Figure 14. Stream flow rates in Wadi Zomer
Figure 15. Water supplied to proposed agricultural areas

In this scenario, there will still be a water deficit of 13.5 MCM for irrigation demand in the study area, as most of the wastewater will continue to cross the border to Israel. Only 1.5 MCM of treated wastewater will be used for agriculture in the Nabulus area. Reuse of the remaining 6 MCM will be costly as it requires investment in a full infrastructure scheme to transfer the treated water to remote areas. As shown in Figure 16, Nablus farmland area has all their treated wastewater needs, but the Tulkarem area needs 14.5 million cubic meters.
Scenario 3: Represents the situation in which a treatment plant is built to the west of Nablus to treat wastewater produced in the western part of Nablus and surrounding villages, represented in the model by the node “Nablus City”. The treated wastewater is used in nearby agricultural areas, represented in the model by the demand node “Nablus_Agr”. In addition, another treatment plant is built next to Tulkarem, to treat wastewater from the Tulkarem area and the treated effluent is used in Tulkarem agricultural areas, represented in the model by the demand node “Tulkarem_Agr”.

Figure 17 below illustrates wastewater flow rates along the valley where there is a four-point measurement. The red line shows that six million m$^3$ of wastewater flows into the valley from the Nablus treatment plant because of a lack of arable land. The yellow and blue lines show that wastewater flow across the Israeli border will be zero in the case of two treatment plants being establishment.
Figure 17. Stream flow

Figure 18 below shows that the irrigation demand for the Tulkarem agricultural area is about 13.5 MCM in 2014. If the Tulkarem WWTP were to be built, the forecast deficit of 4 MCM in 2035 would need to be supplemented. The Nablus agricultural area needs 1.5 million cubic meters for irrigation and the west Nablus WWTP will cover this amount.
Figure 18. Water deficit demand for agriculture in scenario 3
4.6 Conclusions and Recommendations

Water resources management in surface watersheds is important in order to achieve high efficiency in water demand management. The estimated water demand for irrigation purposes in the study area is 17.5 MCM. However, there are only 2.8 million cubic meters available from groundwater sources. Therefore, most of the land is threatened by desertification if no concrete steps are taken to provide the required water for agriculture from unconventional water resources.

The untreated wastewater flow rate in the Alzomer stream in 2013 was about 6 million cubic meters. Untreated wastewater that flows from the Palestinian territories to Israel is treated there, at the expense of the Palestinians, and is reused for irrigation purposes in Israel. The expected annual volume of wastewater to be generated by 2035 in the study area is 14.8 million cubic meters, and this amount is sufficient to cover the agricultural water demand in the study area, if treated and used efficiently.

A wastewater treatment plant for communities in the province of west Nablus was constructed at a cost of 30 million Euros and the plant became operational in 2014. This plant will treat about 3 million cubic meters in 2014 and is designed to treat 8 million cubic meters by 2035. Farmland in the west Nablus province needs only 1.5 million cubic meters per annum and 6.5 million cubic meters needs to be transferred annually to be reused in other areas. The cost of the transfer system, reservoirs, carrier lines, and pumps for this to work is significant. The alternative is to discharge the treated water to the existing carrier line for untreated wastewater, wasting money in unnecessarily treating 6.5 million cubic meters of wastewater annually.

The Palestinian side is currently paying about US$2.2 million annually to the Israeli side for treatment of 6 million cubic meters of wastewater that flows from the West Bank to Israel and this
will increase to US$6.4 million by 2035. The Israelis sell the treated wastewater to local farmers, without an agreement with or compensation to the Palestinian side who provide the raw material.

The construction of two WWTPs in the study area, the first with an annual capacity of 1.5 million cubic meters to serve part of the western province of Nablus and a second with a capacity of about 13 million cubic meters per annum in the Tulkarem area, is the best solution to take advantage of all treated wastewater to be reused in agriculture locally. This would also preserve available groundwater for drinking purposes and would create new jobs in the agricultural sector.
Chapter 5

Cost Benefit Analysis Model for Treated Wastewater Use in Agricultural Irrigation: Four Palestinian Case Studies

Abstract

Worldwide, water scarcity is becoming one of the major limiting factors of economic development and social welfare provisions. Both limited access to and shortage of water sources, affect the agricultural sector, and this is one of the main economic pillars in Palestine, considering the growing demand for food security. The beneficial uses of treated wastewater (TWW) for agricultural purposes are to increase irrigated land and enhance agricultural production. This paper aims to present the cost and benefit analysis (CBA) of treated wastewater use in Palestine focusing on four types of famous crops (fodder, palms, olive, and almond trees) at three different locations of wastewater treatment plants (WWTPs). Results obtained indicated that use of treated wastewater in agricultural irrigation is economically feasible within Palestinian territories. Use of one million cubic meters (MCM) of TWW in palm cultivation results in financial returns of US$2 million. Meanwhile, irrigation of fodder, olive, and almond trees achieve about US$1 million per MCM of TWW. As a source of TWW, use of TWW from sewage works and facilities erected in Palestinian territories is economically feasible more than using TWW imported from Israeli wastewater treatment plants.

5.1 Introduction

It is becoming clear that developing new water sources will not be enough to meet the current challenges of water scarcity; it must be coupled with more efficient use of existing sources of

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4 This chapter was published in GLOBAL JOURNAL FOR RESEARCH ANALYSIS 2277-8160 12/2015; 4(12):336
water by water demand management measures, water reuse and maintaining water quality (Aliewi, 2010). Water demand management in the agricultural sector requires the establishment of incentives, regulations, and restrictions that will help, guide, and coordinate the farmers' behavior for the efficient use of water in irrigation while encouraging water saving technologies. The survival of the agricultural industry depends on saving water and making water use efficiency as high as possible (Hanjra et al., 2012).

Treated wastewater (TWW) is considered a continuous, renewable, and reliable water source, year round, as long as people drink and use potable water (Vedachalam, 2012). TWW as an alternative water source can be used for irrigation; hence, it will reduce the pressure of demand on the conventional water resources. TWW is independent of the winter season. Even during drought periods, wastewater is produced constantly (Toze, 2006).

There are economic benefits from using treated wastewater in irrigation. This will increase the irrigated agricultural area and thus increase agricultural production (AQUAREC, 2004). The agricultural sector contributes significantly to the Palestinian economy as Palestine is characterized by the production of many agricultural crops due to the diversity of climate and terrain. Palestine suffers from water scarcity caused mainly by the lack of control over the Palestinian water resources, among other reasons (Almasri, McNeill, and Mizyed, 2007).

A cost-benefit analysis (CBA) is one of the most widely accepted economic tools to support decision making rational (Cellini and Kee, 2010). The method(s) followed in the evaluation process in the CBA is to use market prices to assess the costs and benefits, known as the “financial analysis”.

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5.2 Agriculture Sector Challenges in the Study Areas

The amount of fresh water allocated for agriculture will be reduced drastically to meet the increasing demand for municipal use. The irrigation water shared in Palestinian territories is threatened by the challenges to subsidize other sectors with each of their water demands, but also to meet the increasing water needs for people in the future (PWA, 2012). Treated wastewater reuse (TWR) in agriculture in semi-arid regions has become a necessity. The reuse of treated wastewater in the Palestinian agricultural sector has promising aspects due to a number of perspectives:

- Sewage is a problem for public health and the environment.
- There is no other unconventional alternate water source in the Palestinian territories for agriculture (no sea water).
- The cost of TWR is low when compared to the cost of other alternatives, such as importing desalinated sea water from the region.
- Wastewater sources are reliable and a relatively constant source of water supply and thus play an important role in reducing uncertainty in the water sector (PWA, 2014).

However, while the TWR is extremely useful for all of these reasons, the use of treated wastewater in Palestine has its own special importance as it will become a constant and controlled water source and will be positively reflected on the national economy development. Therefore, it is necessary to evaluate the possibility of TWR and the different locations for agriculture irrigation (Haddad, 2012).

The total arable land in the West Bank and Gaza is about 2.2 million acres and the estimated percentage of area planted is 84.5% (87% of which are rain-fed agriculture and 13% irrigated
agriculture). In the West Bank, the proportion of agricultural area is 91%, which is equivalent to 1,650 thousand acres and in Gaza, the proportion of agricultural area is 9%, which is equivalent to 165 thousand acres (Yaqob, 2015). The Palestinian agricultural sector played an important role in the Palestinian national economy, despite the fact that the agricultural sector's share in the Palestinian economy has declined. In the 1970s, the agricultural production ratio fell from 45% to 35% of the gross national product and in the 1980s, the drop ranged between 38% and 28%. Then in 1993, the percentage dropped to 19% and decreased to 5.5% in 2010 (PCBS, 2014).

This paper explores the economic benefits of treated wastewater reuse in agriculture considering the basis of comparisons of net benefits for TWW reuse in irrigation from WWTPs in the West Bank compared with those in Israel.

5.3 Methodology

This section explains the methodologies that are applied to estimate the cost and benefit of treated wastewater reuse in irrigation in the Wadi Zomer area (Figure 19). The CBA covers the following scenarios:

Scenario 1: Reuse of treated wastewater generated from the Nablus treatment plant only with the remainder discharging across the Green Line.

Scenario2: Reuse of all TWW generated from the Nablus and Tulkarem treatment plants with zero discharge across the Green Line.
Scenario 3: Reuse of treated wastewater from the WWTP inside the Green Line and pumped back to the Zomer catchment area.

The EPANET program was used to design the pumps, conveyance lines, and storage tanks for Scenario 3 as shown in Figure 20.
5.3.1 Wastewater Quantities

Figure 21 below illustrates that the generated amount of wastewater to be produced in 2015 is 3.3 million cubic meters for Scenario 1 while the amount of wastewater from Scenario 2 to be produced is 7 million cubic meters and this will be treated in both the Nabulus WWTP and Tulkarem WWTP. However, the total quantity is to be treated in Israel for Scenario 3. Effluent treated wastewater is calculated to be 75% of the total generated quantity, taking into consideration the losses in the trunk lines and losses during treatment operations. The quantity of treated wastewater that will reach agricultural land is assumed to be 75% of the effluent amounts, taking into consideration the leakage and other losses in the conveyance systems. This is equivalent to 56% of the total generated wastewater in the area. During the dry season (nine months per year), the total available amount of treated wastewater can be utilized. However, during the rainy season, there is only a need for 25% of this quantity.

![Wastewater Quantities in MCM for 2015](image)

**Figure 21:** Wastewater quantities in 2015
In 2035 the amount of wastewater generated and treated in the study area will be almost doubled compared to year 2015. Figure 22 shows that the wastewater generated in the study area in 2035 is calculated to be 8 million cubic meters for Scenario 1 while it is 15 million cubic meters for Scenarios 2 and 3.

![Wastewater Quantities in MCM for 2035](image)

**Figure 22.** Wastewater quantities in 2035

### 5.3.2 Agricultural Land Area

According to the type of soil and its physical and chemical characteristics, the agricultural land areas are classified into three types. The first one is a high-value type, which is used in vegetable cultivation. Palestinian specifications and standards prevent the use of treated wastewater for vegetable irrigation, so it is only allowed to be used to irrigate trees and livestock feed. The second is a medium agricultural value type, which occupies an area of 6,400 dunums and the third is a low-value type, which occupies an area of 78,319 dunums.
Treated wastewater can be used to irrigate medium and low agricultural land types, based on the Palestinian standards. The following crop types of fodder, palm, olive, and almond trees were studied when irrigated by TWW.

Figures 23 and 24 show that there is adequate agricultural land area for the total quantity of treated wastewater generated in the study area and there will be no need to transfer any amount of TWW to other areas or Israel.

![Graph showing area needed for irrigation by treated wastewater in 2015](image)

**Figure 23.** Agriculture land needed for reuse of TWW in 2015
Figure 24. Agriculture land needed for reuse of TWW in 2035

Figure 25 below shows that in year 2035 in the case of “feed”, the maximum land needed is 59% of the medium value land. In the case of “palm”, the maximum land needed is 110% of the medium value land. This translates to 64 dunums in 2035 needed to use all the produced treated wastewater quantities within the study area and this area can be used from low-value land.

Figure 25. Agriculture land needed vs. available for TWW reuse in 2015 and 2035
5.3.3. Production Values of Irrigated Crops

Production values of irrigated crops are estimated by multiplying the total dunums of land to be irrigated by the production value of one dunum cultivated. Based on data obtained from the Ministry of Agriculture (ARIJ, 2012), the production value of land cultivated with animal fodder is US$2,000/dunum, the production value of land cultivated with almonds is US$1,428/dunum, the production value of land cultivated with olive trees is US$1,131/dunum, and the production value of land cultivated with palm trees is US$5,143/dunum.

5.4 Results and Discussion

This section represents the results of a costs and benefits analysis of wastewater treatment reuse in agricultural irrigation in the Zomer catchment area. The analysis covers the costs and benefits for seasonal reservoirs, TWW conveyance lines, pumps, and drip irrigation systems. The analysis covers the periods 2015 and 2035.

5.4.1 Investment Costs

The investment costs for the treated wastewater reuse conveyance system including the pumping facilities, conveyance lines, storage facilities, and irrigation systems are estimated for year 2015.

5.4.2 Capital Expenditures (CAPEX)

5.4.2.1 Seasonal Reservoirs

Two reservoirs are needed for Scenarios 1 and 2 with storage capacities of 33,000 m$^3$ and 61,650 m$^3$ to store water from two days’ worth of capture of treated wastewater quantities in 2035. The capital expenditures for the storage reservoirs are estimated at US$120/m$^3$ (Jass, 2015).
5.4.2.2 Conveyance Lines

For Scenarios 1 and 2, a steel pipe with a diameter of 250 mm is required as a conveyance line from the WWTP to the irrigated area. The estimated capital cost per meter is US$100 which includes supply, excavation, bedding, backfilling, fitting, pipe installation, reinstatement, cleaning, and testing (Tahsien, 2015).

The length of line required for Scenario 1 from the Nablus treatment plant to the Nablus irrigated area is estimated to be 4 km and to the Tulkarem irrigated area is 4.5 km. For Scenario 2, the length of lines needed from the Tulkarem treatment plant to the upstream irrigated area is estimated to be 10 km and to the Tulkarem irrigated area is 8 km. For Scenario 3, two diameters are needed (500 mm and 750 mm) for a total length of the force main of 25 km. The estimated capital per meter run is US$500 and US$700 respectively, which includes the cost of supply, excavation, bedding, backfilling, fitting, pipe installation, re-instatement, cleaning, and testing.

5.4.2.3 Drip Irrigation Schemes

The CAPEX for the drip irrigation systems is set at US$200/dunum (Hammad, 2015). The total area of irrigated land is determined by dividing the volume of treated wastewater available for irrigation by the volume of water required to irrigate one dunum of land of a specific crop. The total water demand for the crops (feed, almond, olives, and palm trees) to be irrigated with treated wastewater is 600-1,700 m³/dunum/year (Ashqar, 2015).
Table 10 Drip Irrigation Network Cost

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Scenerio 1</th>
<th>Scenerio 2</th>
<th>Scenerio 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fodder</td>
<td>621,885</td>
<td>750,368</td>
<td>750,368</td>
</tr>
<tr>
<td>Almond</td>
<td>1,762,009</td>
<td>2,126,042</td>
<td>2,126,042</td>
</tr>
<tr>
<td>Olives</td>
<td>1,510,293</td>
<td>1,822,322</td>
<td>1,822,322</td>
</tr>
<tr>
<td>Palm</td>
<td>881,004</td>
<td>1,063,021</td>
<td>1,063,021</td>
</tr>
</tbody>
</table>

5.4.2.4 Pumping Facilities

For Scenario 1, there is no need for pumping facilities as the identified agricultural area can be irrigated by gravity from the Nabulus Treatment Plant.

For Scenario 2, about half of the treated wastewater needs to be pumped from the Tulkarem WWTP to the upstream agricultural areas. To capture the treated wastewater in 2035, two sets of pumps are needed to pump 4 MCM to a level 240 m above sea level.

For Scenario 3, treated wastewater needs to be pumped from Israel to Nablus and Tulkarem agricultural area in two stages. Three sets of pumps are needed to pump 11.25 MCM to a level 240 m above sea level in the first stage, and 5.75 MCM will be pumped from 240 to 540 m above sea level in the second stage.

According to the design prepared by adopting the EPANET program (Weshahi, 2015), the following components are needed:

- booster pumps (3 x 1000 m³/hr @ 240 TDH) and booster pumps (3 x 500 m³/hr @ 300 TDH) with two pumps in operation and one on standby. The cost of which are US$7 million and US$5 million including civil, mechanical, and electrical work in
addition to the construction of two water balance reservoirs with a capacity of 15,000 m³

- transmission pipeline DN 750 mm and transmission pipeline DN 500 mm

The above mentioned prices were obtained from suppliers and contractors (Arabtech Jardanea, 2015).

Table 11 Estimated Capital Costs for the Conveyance Systems of the Three Scenarios

<table>
<thead>
<tr>
<th>Capital Expenditures (CAPEX)</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Reservoirs</td>
<td>3.96</td>
<td>7.4</td>
<td></td>
</tr>
<tr>
<td>Conveyance Systems</td>
<td>0.85</td>
<td>1.8</td>
<td>15.5</td>
</tr>
<tr>
<td>Pumping Stations/Boosters including the Balance Reservoirs</td>
<td>3</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Total Capital Costs (M USD)</td>
<td>4.81</td>
<td>12.2</td>
<td>27.5</td>
</tr>
</tbody>
</table>

5.4.3. Operational Expenditures (OPEX)

The annual operational expenditures (OPEX) for the water facilities are assumed to be 5% for the boosters and 2% for the conveyance lines and storage reservoirs of the CAPEX with an assumed annual increase of 1% of these costs (Abu-Madi, 2006). The annual operational expenditures reflect the annual running costs for the conveyance schemes. Table 13 below shows the NPV calculation for the O&M expenditures for the three scenarios.
Table 12 Net Present Value for Operation and Maintenance Expenditures

<table>
<thead>
<tr>
<th>O &amp; M NPV (USD)</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Reservoirs</td>
<td>175,744</td>
<td>328,322</td>
<td>0</td>
</tr>
<tr>
<td>Conveyance Lines</td>
<td>37,985</td>
<td>79,884</td>
<td>687,888</td>
</tr>
<tr>
<td>Booster PS</td>
<td>0</td>
<td>426,607</td>
<td>1,706,428</td>
</tr>
<tr>
<td>Total O&amp;M NPV ($)</td>
<td>213,729</td>
<td>834,813</td>
<td>2,394,316</td>
</tr>
</tbody>
</table>

5.4.4. Unit Costs

The unit costs are calculated by taking the total net present value per each crop (Capex + Opex) divided by the available TWW per each scenario. Table 14 shows that the unit costs per each crop for Scenario 3 are higher than Scenario 1 and Scenario 2. Also, it shows that unit cost for the almonds is the highest and that the cost of fodder is the lowest.

Table 13 Cubic Meter Cost for Each Agricultural Type and Scenario

<table>
<thead>
<tr>
<th>Unit Costs (US$/m³)</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fodder</td>
<td>1.26</td>
<td>3.06</td>
<td>6.81</td>
</tr>
<tr>
<td>Almond</td>
<td>1.51</td>
<td>3.37</td>
<td>7.12</td>
</tr>
<tr>
<td>Olives</td>
<td>1.45</td>
<td>3.30</td>
<td>7.05</td>
</tr>
<tr>
<td>Palm</td>
<td>1.31</td>
<td>3.13</td>
<td>6.88</td>
</tr>
</tbody>
</table>

5.5. Benefits from Using Treated Wastewater for Irrigation Crops

There are many benefits that will result from using treated wastewater in agriculture including the environmental, social, and health benefits. The direct benefit discussed here is the increase in the production of agriculture due the increase of available water for irrigation.
Table 15 represents the production value per each crop and scenario. The production value for palm trees is higher than others crops for the three scenarios.

Table 14 Crop Production for the Three Scenarios

<table>
<thead>
<tr>
<th>Crop Production (US$/m³)</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fodder</td>
<td>4.63</td>
<td>3.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Almond</td>
<td>8.86</td>
<td>6.78</td>
<td>6.78</td>
</tr>
<tr>
<td>Olives</td>
<td>6.36</td>
<td>4.95</td>
<td>4.95</td>
</tr>
<tr>
<td>Palm</td>
<td>16.87</td>
<td>13.12</td>
<td>13.12</td>
</tr>
</tbody>
</table>

The net benefit per cubic meter of TWW is the cost per each crop which is the crop production minus the cost per each cubic meter of treated wastewater. Table 16 shows that Scenario 1 is the best option in terms of economic and financial returns to farmers and palm cultivation is the best type of crops.

Table 15 Benefits from Using TWW in Agriculture

<table>
<thead>
<tr>
<th>Net Benefit (US$/m³)</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fodder</td>
<td>3.38</td>
<td>0.54</td>
<td>-3.21</td>
</tr>
<tr>
<td>Almond</td>
<td>7.35</td>
<td>3.41</td>
<td>-0.34</td>
</tr>
<tr>
<td>Olives</td>
<td>4.91</td>
<td>1.65</td>
<td>-2.1</td>
</tr>
<tr>
<td>Palm</td>
<td>15.56</td>
<td>9.99</td>
<td>6.24</td>
</tr>
</tbody>
</table>

Figure 26 below represents the net production value per crop for each scenario. It shows that the net production values for both Scenarios 1 and 2 are positive, while it is negative for Scenario 3.
This means that the value of production will not cover the capital and operational costs for conveyance systems in Scenario 3.

![Net Production Value per Crop US$](image)

**Figure 26:** Net production value per crop and scenario in USD.

### 5.6. Conclusion and Recommendations

The paper presents several answers to decision-makers’ questions concerning the reuse of TWW in irrigation considering different scenarios for the location of the WWTP and different types of crops. Cost benefit analysis for the different scenarios shows that treating wastewater and reuse inside the West Bank is more cost effective and has a higher positive financial impact and return of more than 150% comparing with treating Palestinian wastewater inside Israel and pumping it back for reuse in the West Bank. Concerning agricultural crops, palm cultivation is the best feasible scenario compared with the other three crops. Meanwhile, animal fodder is the least feasible scenario. The generated wastewater in Palestine is expected to be 200 million cubic meters in 2035 and the reuse of treated wastewater will provide benefits ranging from 200 to
1,000 million USS per year, depending on the crop types and the components of the reuse system.
Chapter 6

6.0 Conclusion and Recommendations for Future Work

6.1 Conclusions

Wastewater plays a key role in any given water policy envisioning an integrated management of water resources. Considering treated wastewater (TWW) as an additional water resource preserves and enhances water resources availability. TWW not only in arid and semi-arid countries but water-rich countries provides an alternative non-conventional water source to meet diverse water needs, reduces water pollution, and protects aquatic ecosystems. Hence, riparian conflict on transboundary wastewater management is a coin with two eco-political faces: ecologically, a pollution source and politically, a water source against water scarcity. Analysis of the published literature on efforts provided by neighboring countries in solving transboundary wastewater conflict revealed the following main obstacles:

- The stronger party attempts to impose high design criteria and effluent quality standards upon the weaker party.

- The restrictions imposed upon the weaker party which prohibits discharge of treated effluent of lower quality into seasonal valleys causes increased capital and annual running costs of wastewater treatment plants (WWTPs).

- The third element is the definition of high sensitivity areas for pollution because this element can lead to the relocation of proposed wastewater treatment plants in other less sensitive zones.
Considering the conflict on transboundary wastewater management between Palestine and Israel, the effluent quality of discharged wastewater is enhanced due to natural treatment (self-purification) during its flow in seasonal streams. Comparative analysis of the current situation of discharging wastewater from the West Bank towards Israel with the establishment of WWTPs in Palestinian communities showed that the investment and operational costs for the wastewater systems are almost the same in the both alternatives. Analysis of the current situation revealed no significant benefits for the Palestinian side if wastewater is discharged towards Israel. However, if wastewater is managed within Palestinian areas, the Palestinian side will gain both economic and environmental benefits compared with the first option.

The Water Environmental Assessment and Planning (WEAP) model output indicated that the estimated annual water demand for irrigation purposes in the study area is 17.5 MCM. However, there are only 2.8 million cubic meters available from groundwater sources while the raw wastewater discharge in Wadi Zomer during 2013 was about 6 MCM. The expected annual volume of wastewater to be generated by 2035 in the study area is 14.8 MCM, which is sufficient to cover the agricultural water demand if treated and used efficiently. The Palestinian side is currently paying Israel annually about US$2.2 million for the treatment of 6 MCM of wastewater that flows from the West Bank to Israel and this will increase to US$6.4 million by 2035. Israel sells treated wastewater to local farmers without an agreement with or compensation to the Palestinian side who provide the raw material.

A cost benefit analysis model for the different scenarios for the location of the WWTP and different types of crops showed that treating wastewater and reuse inside the West Bank is more cost effective. This approach has a higher positive financial impact and return of more than 150% comparing with treating Palestinian wastewater inside Israel and pumping it back for reuse.
in the West Bank. Concerning agricultural crops, palm cultivation is the best feasible scenario compared with the other three crops; meanwhile, animal fodder is the least feasible scenario. The generated wastewater in Palestine is expected to be 200 MCM in 2035 and the reuse of treated waste water will provide benefits ranging from 200 to 1,000 million US$ per year, depending on the crop types and the components of the reuse system.

6.2 Closing the Research Gap in Transboundary Wastewater Management

Both economic development and industrialization lead to increased environmental pollution while increasing the living standards of citizens. However, the economic level of any nation reflects a key factor in public health and environment quality. The economic status of neighboring countries governs the level of environmental quality and public health of citizens. When the environmental problem has a transboundary character, the level of environmental management faces challenges. In this study, management of transboundary wastewater was taken as a case. Therefore, further research studies are needed in other fields of transboundary wastewater management including property (rights or needs), diverse management system structures, treated wastewater standards and quality, the allocation of sewage treatment costs, economic efficiency, environmental sustainability, and an appropriate way of reducing the costs of pollution.

The specific aspects of management for transboundary wastewater along two or more states of different political powers, economic or operational capacities to deal with pollution, or policies to address this problem are of priority research considering the potential impacts of the regional management of TWW on cooperation or hegemony.
Costs for the removal of cross-border pollution loads between states lack legal clarity, political feasibility, and perceptions of justice. Therefore, closer research on these issues is needed aiming at the analysis of the potential impacts of the costs and burdens imposed on all economic and political imbalance principles. There is a need to study whether the processing power disparities through the adoption of the principle of equal pay is more effective in the long run than the ability to pay compensation.

6.3 Future Work

- Successful and sustainable transboundary wastewater management calls for innovative methods to engage the public and private sectors at local, national, and cross-border levels. Future research should concentrate on detailed conflict analysis pertinent to identification and understanding of the benefits, interest, position, impact roles, weight, and effects in order to draw a clear map of the environmental conflict analysis.

- Focus of further research on transboundary wastewater management of cross border communities should reflect the environmental needs of regional ecosystems of downstream users. Future research questions can entail the improvement in ecosystem management, including agriculture, wet land, riparian management, and the steps to mitigate the impact of sewage into streams, rivers, lakes, and coastal environment. The possibilities for nutrient reuse in agriculture or generation of biogas from sewage sludge can also be identified.

- The study of the management of transboundary wastewater under unequal and variable power conditions between neighboring countries is warranted. Lack of technical and legal references for transboundary wastewater management is a research gap. A call for urgent research to find a
socio-technical and enviro-economical acceptable effluent standards is needed. Just and fair legal guidelines governing state negotiations on transboundary wastewater management is of priority.

- Linking drinking water supply and sanitation projects in economic terms warrants a close study. Innovative financing models for sustainable sanitation facilities impact on water supply projects is vital since access to safe drinking water is a human right. On the other side, water pollution reduction is the duty of water users bearing the environmental cost of returning water quality back to its natural status.
REFERENCES


Arabtech Jardanea, J. (2015, 09 05). Booster pumps and pressures pipes Prices. (E. Yaqob, Interviewer)


Benny. (2013, 8 14). Environment officer in the Israeli Civil Administration. (me, Interviewer)


Hassan Ashqar, , M. (2015, 6 5). Soil and irrigation . (E. Yaqob, Interviewer)


Interview with ‘Adel Yassin. (2012, August 5). Director of Sanitation Department in the Palestinian Water Authority, wastewater sector status in Palestine. (E. Yaqob, Interviewer)


