Feasibility of Membrane Based Treatment Technologies for Brackish Water Desalination and Effluent Reclamation in the Jordan Valley

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Birzeit University, 2013/2014

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List of Abbreviations:

ADS	Arab Development Society
ANERA	American Near East Refugee Aid
AOAD	Arab Organization for Agricultural Development
ARIJ	Applied Research Institute/ Jerusalem
BOD	Biological Oxygen Demand

BWRO	Brackish Water Reverse Osmosis
CM	Cubic Meter
CM/D	Cubic Meter per Day
CMWU	Coastal Municipalities Water Utility
CM/Y	Cubic Meter per Year
COPSCO	Consolidated Palestinian Steel Company
DMP	Desalination Master Plan
EC	Electrical Conductivity
EMS	Emergency Municipal Support
EWI	Environmental and Water Institute
GDP	Gross Domestic Product
IWA	Israeli Water Authority
JAIP	Jericho Agro-Industrial Park
JWWTP	Jericho Waste Water Treatment Plant
KSA	Kingdom of Saudi Arabia
MCM	Million Cubic Meters
MCM/Y	Million Cubic Meters per Year
MBTT	Membrane Based Treatment Technology
MEDRC	Middle East Desalination Research Center
MENA	Middle East & North Africa
MF	Micro Filtration
MoLG	Ministry of Local Government
ND	Not Determined
NF	Nano Filtration
NGO’s	Non-Governmental Organizations
NIS	New Israeli Shekel
PARC	Palestinian Agricultural Relief Committee
PPM	Part Per Million
PWA	Palestinian Water Authority
MoA	Ministry of Agriculture
PCBC	Palestinian Central Bureau of Statistics
PH	Power of Hydrogen
PHG	Palestinian Hydrology Group
PPM	Part per Million
PSI	Palestinian Standards Institution

PV	Photo Voltaic
RO	Reverse Osmosis
SBR	Sequenced Bio-Reactors
SMBS	Sodium Meta Bio Sulfite
SPSS	Statistical Package for Social Sciences
SR	Saudi Riyal
SWH	Surface Water Harvesting
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UF	Ultra Filtration
UNDP	United Nation Development Pregame
UNRWA	United Nations Relief and Works Agency
USAID	United States Agency for International Development
WAJ	Water Authority of Jordan
WBWD	West Bank Water Department
WEAP	Water Evaluation and Planning
WW	Wastewater
WWTP	Waste Water Treatment Plant

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Abstract

This research study investigates the feasibility of applying the membrane based technologies for brackish water desalination and effluent reclamation for agricultural use in the Jordan Valley area. The purpose of this research is to identify and evaluate additional water resources to alleviate the water shortage in the Jordan Valley.

The ground water in the Jordan Valley is characterized as brackish water. about 10-12 MCM/Y of brackish water are extracted by the Palestinians from Jordan Valley wells and used for agriculture. This quantity is expected to be improved by additional 6 MCM/Y by developing the old existing wells. The PWA and the MoA estimated the shortage in water demand for both domestic and agriculture uses in the year 2030 of more than 60 MCM. On the other hand, an optimistic water quantities are still available for development such as the brackish water from Fashkha and Malih springs 81–101 MCM/Y and 4 MCM/Y of runoff water harvested from the wades. Furthermore and by the end of 2014, Jericho wastewater treatment plant (JWWTP) will be generating 2450 cubic meter per day (CM/D). This quantity will be gradually increasing to reach its maximum capacity by 2025 with 9900 CM/D which equals to 3.6 MCM/Y of treated effluent water from Jericho sewage collection and treatment system which can be considered as an alternative option to reduce the gap between available resources and the growing demand for Agricultural water in the Jordan Valley.

Currently 21800 ha of irrigated lands are used for agriculture whereas, 221 ha are still available for development.

The research methodology was based on evaluating the available brackish water quantities in the study area, collecting baseline data on existing desalination and wastewater treatment plants in the study area, evaluating beneficiary's awareness and perception to use desalinated brackish water and treated effluent, this was measured by designing, distributing and analyzing a questionnaire survey to the target beneficiaries, Furthermore, a total of 162 wells (annex 1), 4 desalination plants (annex 2) and 6 wastewater treatment plants have been surveyed (annex 3).

The research has investigated several alternatives for utilizing the brackish water and treated effluent in the Jordan Valley. The research proved that the use of reverse osmosis (RO) technology for treating brackish water wells in the Jordan Valley is the most competitive alternative comparing with other desalination technologies, RO will be more feasible when combined with other alternatives to minimize the cost and improve the efficiency such as blending the brackish water with treated effluent generated from wastewater treatment plants (WWTP) or blending with runoff water harvested from neighboring Wadies and also by combining with off-grid Photo Voltaic power (PV) to minimize the energy cost produced by traditional power sources (Diesel generators or electricity grid). RO was selected for its low

energy consumption, market availability, and also for its simplicity in operation and maintenance and the ease of being coupled to off–grid solar PV.

Although the research has proven the economic feasibility of RO technology comparing with other desalination technologies but still the cost is higher than being tackled by low-income farmers in the Jordan Valley, therefore, support of governmental and non-governmental organizations (NGO's) will be needed.

The feasibility of the Membrane Based Treatment Technology (MBTT) has been examined by evaluating the available resources for agricultural water in term of quantity and quality including the potential for future development whereas, financial feasibility has been evaluated by comparing the cost of R.O desalination using two different sources for power supply such as public electricity grid to the off-grid connected RO-PV, also to the cost when blending the brackish water with treated effluent or harvested run off water.

Comparison was tested on an operating desalination plant in Zbeidat village. The economic calculation has shown that the average produced water cost estimated to be $ 0.183 (USD)/CM for RO-PV desalination compared to 0.166 and $ 0.346 (USD)/CM estimated if power obtained from public electricity network or diesel generators.

By giving the fact that the baseline data for this research based on the assessment of farmer's and public perception for reusing of desalinated water and treated effluent, a field survey's has been conducted in order to analyze the existing situation, understand the needs and define gaps in the existing agricultural water management pattern. Several parameters has been measured and data were collected by means of questionnaire designed based on a set of predefined indicators related to the study. The survey analysis showed a low level of awareness on desalination and effluent reuse, high rejection to the treated effluent when used directly but less rejection when effluent blended with desalinated or run off harvested water. Most farmers considered that the best affordable price for agricultural water should not exceed 0.2 – 0.4 NIS equals to $ 0.056 – 0.11 (USD) . The results showed that most of the farmers have average potential for land development between 2-6 hectares.

This research taken the wells in the Arab Development Society (ADS) as a case study. ADS is the biggest farmers associations in the Jordan Valley located to the east of Jericho city near the border with Jordan where the high salinity water exists. ADS extends on 7500 ha and owns 24 wells of licensed abstraction of 1.2 MCM/Y, however only 4 wells are operated with average abstraction of 0.631 MCM/Y, other wells are abandoned and requires rehabilitation.

The alternatives proposed for the Arab Development Society wells can be disseminated and applied on other 162 agricultural well in the Jordan Valley of different capacities and water quality in order to overcome the problem of salinity and stop the damage to the soil and crops.

By comparing the research results with the corresponding ones obtained from similar researches showed an acceptable agreement with strong proof that desalination cost has come down and the efficiency improved in the past twenty years.

The final conclusion of this research that the most feasible option to utilize the brackish water in the Jordan valley is by combining the RO technology by other alternatives such as blending with treated effluent or run-off water, Nevertheless, a further investigation on the desalination design capacity and efficiency is still needed as well as the environmental impact of RO, brine disposal and effluent reuse .

Chapter 1

1.1. Introduction

Water scarcity, increasing population, economic growth, pollution, and urbanization are all placing permanent threat to freshwater resources. The gap between supply and demand on freshwater for industrial, agricultural, and domestic use in Palestine and the surrounding Middle East countries is growing at an alarming speed. Meanwhile, in Palestine there is a 100 -110 CM/Y of potential brackish water resources available and discharged to the Dead sea (PWA, 2012) and by the end of 2014 a minimum of 2450 cubic meters of recycled water will be generated by Jericho wastewater treatment every day. This quantity will increase gradually to reach its maximum in 2025 with 9900 CM/D.

Water, which is one of the most valuable natural resources in the Middle East, is currently facing many challenges as the population growth, economic and agriculture development, and an arid climate results in overexploitation of the water resources in the region. These challenges lead to a rapid degradation of the quality of fresh-water resources. Additionally, as a result of the Stalinization and contamination processes (Vengosh and Rosenthal, 1994), rising salinity levels becomes one of the significant signs of water-quality degradation in groundwater. The alluvial Pleistocene wells in the Jericho area/Palestine show high salinity and a high susceptibility to contamination (Khayat et al., 2006).

The salinity caused by natural and anthropogenic sources is threatening the fresh-water resources. A natural reason is that the overexploitation of fresh aquifers results in a rapid decrease of water levels, which then allows lateral as well as upwelling of deep saline waters from neighbouring aquifers. As a result, the overexploited aquifers become saline due to the leaking of salty water (Vengosh and Rosental, 1994).

Responding to the challenges mentioned earlier, some innovative measures and creative initiatives should be considered. The use of reclaimed effluent and the membrane based desalinated technology for brackish water is growing worldwide and the cost of desalination has decreased steadily in the last few years. Desalination becomes a viable solution for water problems.(ADAN, 2011).

The wise application of innovative water and wastewater treatment systems using membrane based treatment technologies improve water independence, food security and economic development in Jericho district.

There is also a need for water management and rational use of water. This implies looking for new resources for potable water and making use of new efficient and effective technologies. There are several aspects for the importance of reclaimed effluent reuse and desalination to provide a future answers for water needs.

This research is going to introduce the assessment of applying the MBTT and the reuse of reclaimed effluent in providing a feasible and sustainable method to utilize brackish and reclaimed effluent in the Jordan Valley area; this is expected to be helpful in improving the water supply that meets the growing demand for drinking, agriculture and industry.

The amount of the available brackish water controls the efficiency of using this technology, in the Jordanian trial the total average flow of brackish springs was 46 MCM/Y and the use of desalination in Jordan is limited to few cases (Mohsen and Al-Jayyousi, 1999).

Palestine is well-known for using the RO technique in desalinating water. In 1993 the first RO desalination plant was established by EMS in Gaza, and followed by two RO plants constructed by Italian development cooperation program, the number of plants keep on growing to reach about 50 units to provide 2 MCM/Y (Ahmed, 2010)., Gaza still lacks an integrated water management system which causes big waste of the available investments, in spite of its precedence in using this technique (Salah et al., 2010).

Decreasing of the water level in Gaza aquifers leads to intrusion of sea water to the aquifer changing 80% of its water to brackish water (Saleh, 2007). Also the untreated wastewater plays major role in increasing the ground water salinity, through 363 sites in Palestine the untreated wastewater is discharged into the environment which plays major role in increasing the ground water salinity (PWA, 2006).

Desalination has become a component of the strategic plan of the Palestinian Water Authority, since the projected domestic water demand by year 2020 is about 182 MCM(PWA, 2006). In Palestine, the experience in desalination using reverse osmosis [RO] technology is new. The first RO plant was constructed in Deir El-Balah, Gaza Strip. People in Gaza have become aware of the deterioration of the quality of the municipal water supply, so they have started to install RO domestic units to solve their problem individually. PWA according to its policy decided to increase the unconventional water resources through adoption of desalination options (Ismail, 2003).

In West Bank the desalination technology is used in Jericho governorate (Jordan Valley) only were brackish water exists in some water wells in the area; most of these desalination projects has been constructed for scientific and experimental purposes.

1.2. Area of study

The area of study is the Palestinian Territories, particularly the Jordan Valley area where brackish waters are viewed as potential and viable resources to alleviate water scarcity and overcome water budget deficit.

The Jordan Valley lies along the eastern side of West Bank. It begins at Bissan moving to the south until Hebron. The valley is combined of 65 communities, 14 acknowledged towns and villages and 50 Bedouin communities(UNICEF and GVC, 2010). 49,390 inhabitants (PCBS, 2007) lives in the Jordan Valley.

Total Area of the Jordan Valley is 161,1723 ha (28.8% of West Bank), where 10,765 ha are of agricultural use (Kubi, 2003), but 6,000 ha of the agricultural land are of limited access do Israeli restriction, further to limitation on marketing due road blockage or checkpoints(Center, 2010), additional reason that hindered the agricultural activity in the area is the available water quality which affected the agricultural production quantities and species(Maan, 2012b). Palm Date is of increasing trend in the Jordan Valley where almost 85,000 tree of different types are cultivated (Maan, 2012a).

The climatic conditions: the Jordan valley is an arid region of hot summer with temperature range (22.4-37.6) C^o and warm winter with temperature variation (7.4-19.3) C^o. Rainfall not exceeding 200 mm/ year over (20-25) rainy days (ARIJ, 1995).

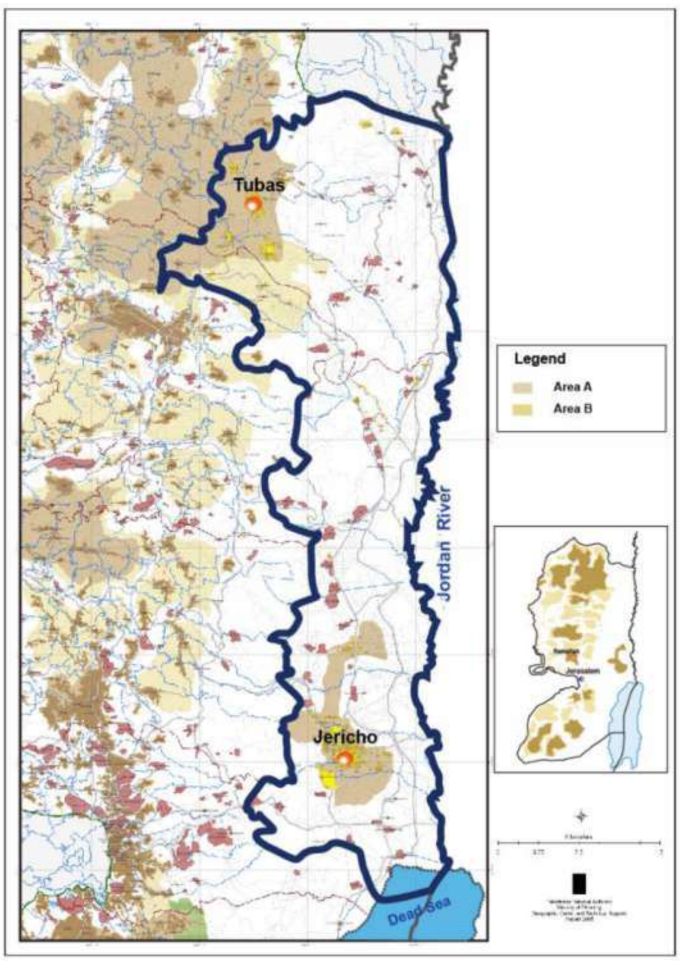

Figure 1: Map for the study area (JICA, 2006).

1.3. Topography and landscapes

The area of study slopes gradually from west to east. The mountainous area is located in the upstream of Wadi Far'a. The elevation reaches up to 600 m above sea level Most of all study areas are covered by foothills with steep slopes, the elevation of the foothills range from 0 to 200 m above sea level, Flat area, which is lower than the sea level and has relatively high agricultural resources, lies along the Jordan River. The length and width of the area is about 10 km and 1 to 2 km, respectively (NIPPON KOEI CO., 2008).

Table 1: Land use and Potential Development in Agricultural land extension (JICA, 2006)

1	2			3	4	5=3+4	6
	Area (Km^2)			**Agricultural Area (Km^2)**	**% of West Bank area**	**% of Area C in Jordan Valley**	**Natural Reserve Area (Km^2)**
	Area A+B	**Area C**	**Total**				
Bardala / Kardala and Wadi Malih	0	275	275	21 (7.6%)	93 (33.8%)	114 (41.4%)	58 (21.0%)
Wadi Far'a and Jiftlik	87	129	216	110 (51.0%)	40 (18.5%)	150 (69.4%)	24 (11.1%)
Greater Jericho	69	278	347	87 (25.0%)	88 (25.3%)	175 (50.4%)	18 (5.1%)
Total	**156**	**682**	**838**	**218**	**221**	**439**	**100**

1.4. Rainfall

The average annual rainfall is 168 mm in the Jordan Valley area, 240 mm in Wadi al Far'a, 429 mm in Tubas, and 554 mm in Jerusalem. The coolest month is January with the mean temperature of 13.3 ^{o} C in Jericho, 14.4^{o} C in Wadi al Far'a, 8.7^{o} C in Jerusalem, while the warmest month is July or August with the mean temperature of 30.0^{o} C in Jericho, 31.4^{o} C in Wadi al Far'a, 23.8^{o}C in Jerusalem. (ARIJ, 1998).

Although the Jordan Rift Valley is extremely dry and surrounded by desert, some areas have groundwater or spring water cultivated by orographic rainfall of the central highlands to sustain agriculture in the Valley. In addition, the warm climate even in the winter makes the valley agriculturally and touristic competitive. (ARIJ, 1998).

1.5. Limited water resources

The West Bank consumes 89.14 MCM/Y, whereas in the Jordan Rift Valley area it is 52.12 MCM/Y, which represents 58% of the West Bank. Likewise, in the West Bank, the optimum water use with leaching requirements is calculated to be 98.14 MCM/Y, and in the Jordan Rift Valley area, 60.24 MCM/Y or 61%. It is clear that irrigation water use in the Jordan Rift Valley area is more than one half of the total in the West Bank, this is due to the fact that the areas with high potential groundwater are located along Wadis, especially as the existing springs and wells are concentrated in lower Wadis. For example, in the Jordan Rift Valley area the annual rainfall is approximately 200 mm. This is the main reason for the high irrigation rate , to make agriculture possible (ARIJ, 1998).

Despite the fact that the Jordan Rift Valley area uses more than one half of all irrigation water, efficiency of irrigation water use in the region, measured in terms of water used per unit area, is the lowest in the West Bank. The urgent challenge then is for the people in the Jordan Rift Valley area to use their limited water resources efficiently in order to maximize their income and employment, while also protecting and restoring the natural environment. In this context, the government should intervene to regulate water usage, to stimulate more efficient use of water resources and to assure sustainability of water resources for future generations (ARIJ, 1998).

1.6. Agriculture

Due to the low quantities of water available to Palestinian farmers, only 6.8% of the cultivated land in the West Bank is irrigated (Brown and Crawford, 2009).

Half of the total agricultural production in the West Bank is from this irrigated land (FAO, 2012).Israel consumes at least ten times more water for agriculture than Palestinians(WB, 2009) irrigating more than half of its cultivated land(IEICI, 2013).Nearly 63% of agricultural land in the West Bank is located in Area C, most of it is in the Jordan Valley and land control policies of the Israeli government's prevent the Palestinians from using this land (Maan, 2012a).

Illegal Israeli settlements in the Jordan Valley grow crops that require large amounts of water, such as bananas, using most of the water pumped from wells in the West Bank; settlers in the Jordan Valley use 81 times more water per capita than Palestinians in the West Bank. (B'Tselem, 2011). Up to $ 500 million (USD) of Israeli settlement products, most of which are agricultural, enter the Palestinian market every year; with total Palestinian agricultural production only about $ 342 million (USD) in 2011 (Oxfam, 2012).

It is estimated that if Palestinians were allowed a fair share of water resources and if restrictions in area C were lifted, an additional agricultural production worth $ 1.22 billion (USD) could be generated yearly (ARIJ, 2011).

1.7. Relevance and research problem

In general, Palestine is facing a water crisis reflected in limited access to available water resources. The Jordan Valley in specific is facing a challenge of water quantities and qualities. Increased annual demand for agricultural water threatens both water volume and quality. Over extraction of groundwater wells led to reverse drying and deterioration in water quality by increasing the salinity level. On the hand, it is clear that water desalination will be the future solution for solving the deficiency in water supply.

Analysis of literature review and references revealed the following problems in the development of the agricultural sector in the Jordan Valley area:

- Increasing demand for domestic freshwater with increased irrigation water for agriculture
- High salinity of ground water wells in Jordan Valley area (1000 – 10000 ppm)
- Crops damage due to high TDS in irrigation water and soil salinity (Pitman and Läuchli, 2002, Medina, 2004).
- Use of desalinated brackish water alone or blended with treated wastewater is not explored in the Jordan Valley and brine disposal is another challenge.
- Lack of funds to implement such recycling facilities where agricultural use of treated wastewater from Jericho wastewater treatment plan is planned.
- Lack of public awareness on potential uses of brackish water and reclaimed water membrane based treatment.

Figure 2 illustrates in brief the above mentioned problems.

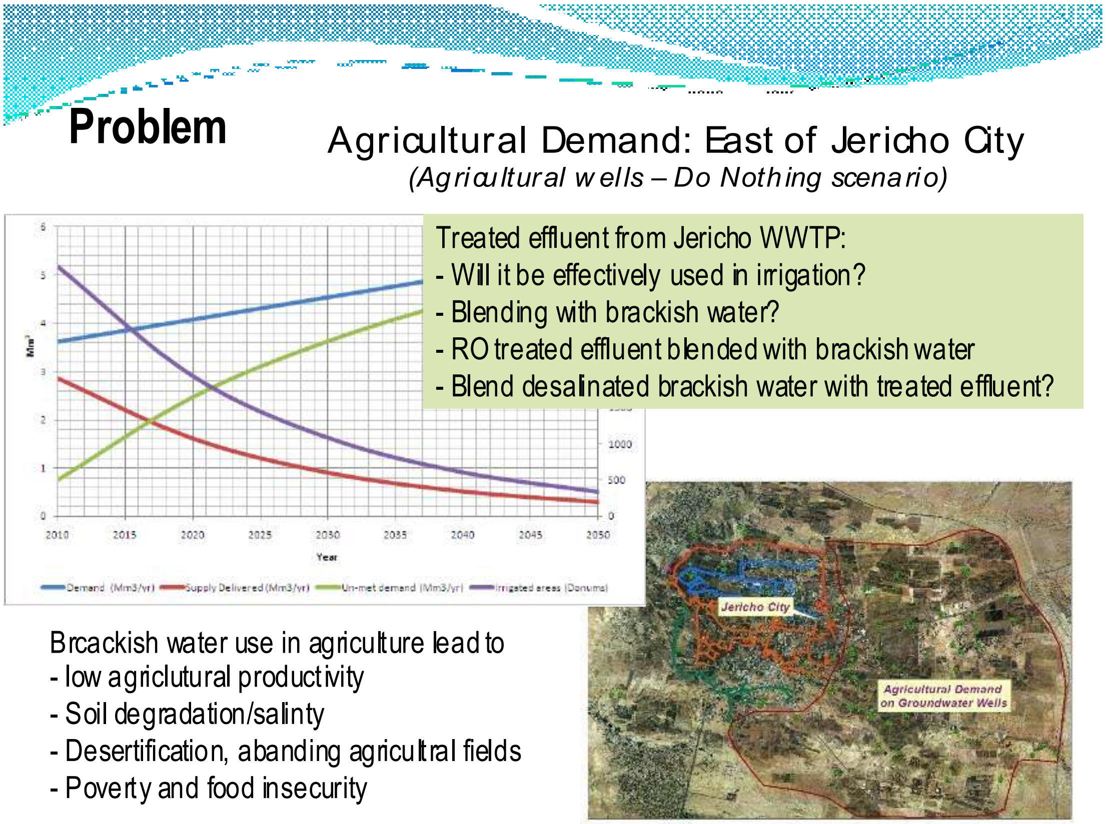

Figure **2**: Estimation of agricultural water demand in Jericho area, modified according to (PHG, 2010).

1.8. Research question

- Considering the available brackish water quantities in the Jordan Valley, will the RO technology be a feasible option for agricultural water production?
- What are the guiding principles behind an adequate blending process?
- Could the reverse osmosis technology prove successful in Palestine as it has been in many Middle East countries?
- Will the people accept desalinated water as alternative water source for domestic, industrial and agricultural consumption?
- What should be the quality guidance for blending waters added post-desalination for stabilization?

1.9. Research objectives

- Evaluating brackish water and reclaimed effluent quantities in the area of study and evaluating the feasibility of membrane based treatment technology and other alternatives for brackish water desalination in the Jordan Valley.
- Assessing farmers' perception for using desalinated water and reclaimed effluent in agriculture.
- Evaluating new alternatives to reduce water withdrawals from the country's overdrawn natural storage bodies of potable water (the two main aquifers) to avoid their further degradation by saline water intrusion (some of it irreversibly) and, eventually, raising their levels to hydrological safe values.
- Reviewing of international standards and guidelines for water quality parameters suitable as for irrigation and acceptable by farmers

Chapter 2

2.1. Literature Review

In this context an extensive literature review pertaining the water effluent and desalinated brackish water reuse has been found. The literature review indicates that there are promising amounts of brackish water in the Palestinian territories mainly in the Jordan River Valley, West Bank and in parts of Gaza strip. Desalination of water proved to be efficient by the use of the reverse osmosis technology. This technology proved to be attainable and applicable in many countries in the region.

2.2. Overview on Desalination

This important and critical area of study has witnessed much interest on the part of researchers and the people concerned in water management. (Dreizin et al., 2008) pointed out that desalination which is separating pure water out of the salt water of seas, brackish aquifers, and wastewater is a great step, This exotic water source with membrane technologies improving and the costs of desalinated water dropping is fast becoming an integral part of Israel's water system. The Ashkelon plant, for example, the first of five new facilities planned in Israel, is the largest reverse osmosis plant in the world, producing 100 MCM/Y, or 15% of the total domestic demand. This plant's successful operation has started to shift the perceptions and decisions of the water community in Israel, and some expect Israel to finally derive half of its water from desalination.(El-Bana, 2000) explained that desalination is expected to participate in solving the water shortages especially in dry regions along seacoasts. But in cities far from a seacoast or in mountains the process will be more costly. Nevertheless, desalination is still considered as the only realistic and best technological hope for dealing with fresh water shortages. Over the past forty years, its uses have grown, particularly in the Middle East with two-thirds of the world's 7500 desalination plants.

The great demand of a safe, sustainable, affordable, and adequate water supply for the world is fostering a renewed interest in desalination and other water treatment technologies(California Coastal Comission, 1993). For this reason a number of technologies have been developed for the desalination of high salinity water, and the selection of the right process requires careful evaluation of process efficiency, plant capital and running costs (Bryant, 1992).

The choice of the desalination process can be determined according to site conditions, applications and local circumstances. Also, use of renewable energy compared to other options can reduce the cost of desalination (Kazmerski, 2011).

2.3. Desalination Background

(Domingo Zarzo Martinez, 2009) has pointed out that the investment costs for brackish water desalination as well as the water production costs, are in general lower than the cost for other applications (drinking water, industrial water), fundamentally based in some reasons: (1) Limited requirements of personnel, chemicals, membrane replacement, (2) Possibility to regulate water production according to electrical tariffs in order to produce water at lower energy cost, (3)Lower requirements about product water salinity (4) Lower requirements of civil works, automation, safety measures to guarantee production.

2.4. Desalination in Gaza

Al-Agha and Mortaja (2005) wrote an article in which they address desalination water management in its embryonic stage in the Gaza Strip. The sources of drinking water supply, distribution system and the environmental impact of brine water were explained in detail. They also talked about the importance of desalination as a solution to the great demand on drinking water in Gaza.

Abu-Jabal et al. (2001) said that the water research center in Al- Azhar university in Gaza with the help of the Ebara Corporation (Tokyo) are doing a great contribution to solve the drinking water in Gaza by using the solar energy and evaporation distillation with triple-effect evaporators.

According to the (Bank, 2009) a small scale desalination – largely private – has emerged as a stop-gap solution. In addition to four public desalination plants run by the Coastal Municipality Water Utility (CMWU) (Production 1000 CDM), there are at least 40 private desalination plants selling water both wholesale for delivery by tanker and retail by jerry can (production about 2,000 CDM).

Most of the private facilities are not licensed by the PWA and even those that are licensed are not monitored, as the water authorities do not have the capacity to monitor the many small facilities. There are also thousands of home desalination plants, which are similarly unmonitored (Amnesty, 2009).

2.5. Desalination of brackish water in Jordan

Jordan experience in brackish water desalination ith he assistance of Japan iternational cooperation agency (JICA) has been discussed by (Jaber and . Mohsen, 2001), (Mohsen and Al-Jayyousi, 1999). They said that although this experience is still limited but they expect more and more interest in this field in the near future.

Mohsen and Gammoh (2010) explained that RO desalination systems are used in the Middle east for getting water as well as oil. They added that desalination of sea water or brackish water is very limited because the Gulf of Aqaba is very far from the Amman where pumping costs a lot of money.

Mohsen and Al-Jayyousi (1999), (Al-Hadidi, 1999) shared the same view above that desalination is the future solution for the problem of the limited sources of water

Table1: Water desalination projects in Jordan

No.	Station	Govt.	Treatment method	Treated water quantity CMH	Capital cost/JD	Finance	Date of est.
1	Ruwaished	Mafraq	Desalination	90	140000	WAJ	2000
2	DeirAlla	Balqaa'	Desalination	50	120000	WAJ	2001
3	Zarqa	Zarka	Desalination	600	750000	WAJ	2002
4	WadiAraba	Aqaba	Desalination	35	120000	WAJ	2002
4	Abu Al-Zegan	Balqaa'	Desalination	1800	2500000	Economic and Transformation Prog.	2003
5	Safawi	Mafraq	Desalination	55	194000	WAJ	2003
6	Al-Omari	Aqaba	Desalination	30	87000	WAJ	2003
7	Mobile unit	Mafraq	Desalination	35	89500	WAJ	2003
8	Mobile unit	Ghor	Desalination	35	87500	USAID	2003
9	Mobile unit	Balqaa'	Desalination	35	87500	USAID	2003
10	Qatar	Aqaba	Desalination	3.5	---	USA govt.	2003
11	Ghor Safi	Karak	Desalination	75	128000	WAJ	2005
12	Ain Sara	Karak	Desalination	55	74000	WAJ	2005
13	Jafr	Ma'an	Desalination	35	134700	Royal Court	2007
14	Al-Gweibeh	Karak	Desalination	15	49000	Ministry of finance	2007
15	Al-Karama Border	Mafraq	Desalination	18	119000	Free Zone Corporation	2007
16	GhorFifa	Karak	Desalination	30	99000	Ministry of finance	2008
17	Al-Kraymeh	Balqaa'	Desalination	100	147000/year	WAJ	2008
18	Al-Rwaished	Mafraq	Desalination	70	102000	Ministry of finance	2008
			Total	3166.5			

2.6. Desalination in Israel

Israel started its implementation of water desalination by the mid-1950s when it extended irrigation pipes to the Negev desert, by this time, desalination had already been employed for drinking water in Eilat. In the late 1950s the Israeli government was presciently investing a relatively large amount on R&D on desalination (Tenne et al., 2012).

Desalination Master Plan (DMP) for the Israel Water Authority's (IWA) in 1997 which was prepared by ADAN Technical & Economic Services Ltd. (ADAN). And discussed by Tenne et al. (2012) has discussed the capacity, location and product water quality of the three large-scale seawater desalination plants currently operating in Israel, Ashkelon, Palmachim and Hadera. In addition, he mentioned that there are two other plants currently under construction, Soreq A and Ashdod, as well as the two plants which are foreseen to be installed by 2020, Western Galilee and Soreq B.

The costs analysis which were driven by the hope to minimize the total investments has been discussed by (Tenne et al., 2012). The cost analysis included the investments in the plants themselves, through economies of scale and utilization of existing infrastructures, and in the investments in the downstream infrastructures that would be required to continuously absorb the desalinated water. The benefits analyses were made in the hope to get the maximum value of desalinated water quantitatively by increasing the reliability of the water supply and qualitatively, increasing GDP and avoiding water withdrawals from the country's overdrawn natural storage bodies of potable water and qualitatively by reducing water supply hardness and lowering the chloride and sodium concentrations in the reused municipal wastewater.

Table 2: Operating and planned brackish water desalination plants in Israel (ADAN, 2011)

No.	Plant name	Plant owner	Flow rate CM/D	Year of Establishment
1	Sabaha A	Mekorot	28,000	1978
2	Sabaha B	Mekorot	10,000	1993
3	Nawe zohar	Mekorot	13,000	2003
4	Kziot	Mekorot	8,600	2003
4	Granot	Mekorot	7,400	2003
5	Gat	Mekorot	4,500	2004
6	Magan Misheal	Magan Misheal	25,000	2004
7	Nawe yam	Nawe yam	6,500	2005
8	South-Hof carmel	--	14,000	2005
9	Hof carmel	Hof hakarmel	3,600	Planned

10	Naaman Kordani	--	15,000	Planned
11	Lahat	Mekorot	18,000	2011
12	Mishor rotem	Mekorot	30,000	Planned
13	Mainot zokim	Mekorot	5,000	Planned
14	Beer ora	Mekorot	6,000	Planned
Total brackish water - active			**31.3 MCMY**	**94,850 CMD**
Total brackish water - planned			**33.7 MCMY**	**102,100 CMD**

2.7. Fundamentals of Membranes for Water Treatment

The history of development and importance of membranes for water purification was investigated by (Zahid Amjad, 1998). They started very traditional and ineffective and ended very advanced and productive. He also talked about three types of membranes: microfiltration (MF), Ultra-filtration (UF), reverse osmosis (RO), and Nano-filtration (NF) membranes; each one of these has its own characteristics.

2.8. Relevant to effluent reuse Agriculture in Jericho

The challenges of waste water management in Jordan valley was discussed by (Al-Sa'ed, 2006). He discussed the existing WWT facilities in Palestine and the potential use of treated wastewater for agriculture. While (Shaheen, 2003) investigated the economic feasibility of wastewater reuse. He distributed questionnaires to farmers and inhabitants in different areas of the West Bank to elicit social acceptance. Wastewater reuse can cover about 10 percent of irrigated agriculture, which contributes 35 percent of the total value of the Palestinian agricultural sector. (Hochstrat et al., 2006) pointed out that recycled water may be the solution of the shortage of water in the future which is a significant low-cost resource development option for agricultural, industrial, and urban potable/non-potable uses. In addition, wastewater collection and treatment is essential to protect public health and prevent environmental pollution. while (Jimenez et al., 2001) emphasized the importance of recycling water for agriculture and irrigation, but he explained that three factors should be considered: pathogenic microorganism content, salinity, and soil permeability.

Lawrence et al. (2003) emphasized the importance of water reuse projects to cope with the increasing need of water in the arid regions. The success of these projects depends on both the effectiveness and the suitability of the technology and the safety and the efficiency of the distribution. Two examples are mentioned to prove the success of water reuse projects: the first in Egypt and in USA.

The success of treated water re-use schemes does not just depend on the effectiveness and suitability of the technology that treats the wastewater. The planning and development of the institutional framework that will monitor control and deliver the treated wastewater — particularly where there are many institutions working in the same or similar areas — is vital for the safe and efficient use of this increasingly important water resource (Lawrence et al., 2003)

Jimenez et al. (2001) also emphasized the importance of recycling water for agriculture and irrigation, but he explained that three factors should be considered: pathogenic microorganism content, salinity, and soil permeability.

In the Master Plan study for Jericho Water System, (PHG, 2010) has collected and analysed important data on farm water use practices and the farmers' perspectives on relevant issues. During this Research several surveys and workshops has been conducted in order to assess the willingness of farmers to use recycled water or blended effluent. The report has provided additional data on the available water quantities for both domestic and agricultural consumption as well as the Physical and Chemical characteristics of ground water in Jericho area.

2.9. Brine effects on soil

Brine has physical and chemical effects on soil. First, it damages the soil's physical properties by increasing the concentration of the sodium accumulated on the surface. In addition, the soil fertility is affected as the high temperature of brine kills microorganisms in soil. The soil is also affected chemically because brine has toxic materials that can damage the structure and composition of soil. It may also affect the soil's capacity to hold water and to transmit plant nutrients. Consequently it will result in a poor soil quality which will definitely affect crop yields (Jimenez et al., 2001)

2.10. Desalination effects on Agriculture

Blending of desalinated with saline groundwater to compensate the essential nutrients lost through RO was investigated by (Ben-Gal et al., 2009) . They found that blending 30% saline water with 70% desalinated water brought Ca, Mg, and S minerals to satisfactory levels.

2.11. Cost and Feasibility

In order to integrate the different elements of the problem (Georgopoulou et al., 2001) wrote a paper in which he outlines a methodology that allows the use of desalinated brackish groundwater, coupled with an effective strategy for controlling seawater intension and enhancement of the hydrologic budget through reuse of treated wastewater into an optimization shell package that can be used for the economic evaluation of the overall scheme and presents some aspects of two of the system elements, brackish water desalination and recharge with treated wastewater

In Al-Jouf area in KSA (El-Ghonemy, 2013) conducted a study about getting the underground water and desalinating it using public electricity or diesel generators in remote areas to drive various types of pumps. In this research he proved that a small scale RO desalination unit is very common in use for producing fresh water from brackish water. (El-Ghonemy, 2013) found out that, specific power consumptions are 3.99 and 3 KWh/CM based on installed and actual power consumption respectively.

Moreover, from the cost analysis, the percentage costs are; 49.4%, 28.66%,8.47%,8.4%,5% for labor cost, chemicals cost, electric power cost, fixed cost, and membrane replacement cost respectively. Also, the production cost resulting from the small BWRO desalination unit is estimated to be 7(SR) /m^3 (about $ 2 (USD) / CM).

The feasibility of the off-grid connected RO-PV (to operate the desalination unit) was compared to Diesel generator and electricity network by (Taha, 2014), environment cost was included. Comparison was tested on operating desalination plant in Marj Na'jeh. The economic calculation has shown that the average produced water cost estimated to be 0.183 USD/m3, compared to $ 0.166 and 0.346 (USD)/m3 estimated if electricity network or Diesel generator.

The cost of BWRO desalination has been estimated by (Glueckstern, 1991), he found that the cost of 1 CM of desalinated water for a 12,500 CM/D capacity BWRO plant is ranges between $ 0.47-0.64/ CM and the investment costs for relatively high saline surface brackish water is approximately $1000 (USD)/ CM/D compared to $ 500 (USD)/ CM/D and unit water cost $ 0.34 - 0.40/ CM for a 25,000 (USD)/ CM/D capacity plant with low salinity water while the specific energy consumption is estimated to 20% of the unit water cost.

Another example has been taken is the (Sabha) brackish water desalination plant of capacity 13,500 (USD)/ CM/D. This plant located in Eilat at the Red Sea shore used to supply 50% of the city water demand. by comparing the operation cost in this plant it was found that the cost has been dropped down from 0.49 in 1981 to 0.3 in 1984 and 0.23 in 1985 with a possibility for further improvement to $ 0.1- 0.2 (USD)/ CM by interconnection with coal, nuclear or solar-pond power stations.

Chapter 3

3. 1. Research Methodology

The following research methodology was applied to achieve the study objectives:

- Data collection from many sources including the following:

- Relevant review of literature
- Data at the governmental and non-governmental institutions including the Palestinian Water Authority (PWA), Ministry of Agriculture (MoA), Jericho Municipality, the Palestinian Central Bureau of Statistics (PCBC), the Palestinian Agricultural Relief Committee (PARC), Applied Science Research Institute in Jerusalem (ARIJ) , Birzeit University and Middle East Desalination Research Center (MEDRC).
- Interview and personal communication with key persons and experts.
- The questionnaires distributed to the stakeholders including farmers and major wastewater generators.

- Evaluation of quantity and quality of ground water in the Jordan Valley area (potable & agricultural uses)
- Assessment of land available to increase the potential of agricultural land
- Evaluation of current desalinating technologies including pilot scale units in Jericho District
- Develop, distribute, collect and analyze field questionnaires pertinent to perceptions and attitudes of farmers, households and general public
- Investigating two case studies (effluent of Jericho WWTP and existing RO systems in Jericho)
- All compiled data were then entered into a special geo-data base that was developed for this research in order to facilitate data management, handling and retrieval. The geo- database includes several types of information related to the water in the area of study.

  The Gio-data base includes maps, aerial photographs, location of groundwater wells, potential abstraction, topography, land uses. wells data, location of desalination and wastewater treatment plants, location of springs and their potential discharge, the main streams and their potential flow and many other types of data.

- The economic analysis including estimation of the Total Costs according to the following equation:

$$Total\ Cost = Investment\ Cost + Operation\ and\ Maintenance\ Cost + Environment\ Cost$$

, (Abu Madi, 2005).

Where,

- Investment cost is inclusive of desalination and Photovoltaic system cost, and was referred to different previous studies and living examples from Zbeidat, MarjNa'jeh(Taha, 2014) , COPSCO and desalination plants.

- Operational and maintenance cost that includes: labor, operational material, testing, replacement of filters, invertors, and batteries (Taha, 2014).
- Cost treated effluent from JWWTP
- And the estimation of the produced water cost is estimated according to the following equation:

- $\text{The average produced water Cost}\left(\frac{USD}{m^3}\right) = \frac{Total\ Cost\left(\frac{USD}{year}\right)}{Total\ Produced\ WAter\left(\frac{m^3}{year}\right)}$ (Abu Madi, 2005).

3. 2. Reviewing previous studies

As Jericho and the Jordan valley have been a center of interest for a number of organizations working in this sector, a number of publications have been produced relevant to this research; these publications have been collected and reviewed at the very beginning of this study.

3. 3. Data collection and storage

Relevant data on population and socio economic aspects have been provided by the central bureau of statistics (PCBS) while the data relevant to water resources, climate, soil and agriculture have been provided by the Palestinian water authority (PWA), the Ministry of Agriculture (MOA) and Applied Research Institute - Jerusalem (ARIJ). Moreover, it compiled several sets of data related to water use, water supply system details, and water - wastewater tariff and water governance from Jericho Municipality.

3. 4. Meetings with stakeholders

During the study, I have conducted several meetings with potential stakeholders in Jericho in order to understand the current situation and to assess the roles and relations of those stakeholders in managing agricultural water in the area. The following were the main stakeholders that were met: Jericho Municipality, Ein Sultan Irrigation Association, Ministry of Local Government (MoLG), Minstry of agriculture (MoA) and the Palestinian Agricultural Relief Committee (PARC) and other individual farmers.

These meetings were necessary to assess the current situation and to introduce the desalinated brackish water and effluent reuse in agriculture as anew potential water source for agriculture and also to better understand how stakeholders can be engaged in this process.

3. 5. Field surveys

Knowing that part of the baseline data depends on the assessment of farmers' and public perception for reusing desalinated water and treated effluent, field surveys have been conducted to analyze the existing situation and to understand the needs and define gaps in the existing water management pattern. Accordingly, several areas to be investigated have been identified. Data were collected through a questionnaire that was designed based on a set of predefined indicators related to:

- Socio economic background: it includes aspects about demography (age/sex and permanent residents) and socio economic variables (education, employment status, average annual income and average annual expenditures for agricultural water.
- Quantity and quality of agricultural water supply: questions about the current water status such as water resources, interruption of water supply, availability of agricultural land and actual water demand in order to assess the satisfaction degree.
- Water supply cost: questions about cost and tariff for agricultural water in addition to farmers' affordability for Agricultural water price.
- Water related practices: include questions related to irrigation methods, types of cultivation, availability of water saving methods and salinity tolerance crops, willingness to pay and the satisfactory price of agricultural water.
- Assessing the farmers' acceptance to use desalinated water and treated effluent
- Perspective of problems which most farmers are suffering from, causes and solutions for those problems. (See questionnaire in Annex 4)

Table 3:Outlines for the feild survey

Number of Samples	Jericho City	15 Respondents
	Jericho Governorate[1]	35Respondents
Survey Method	Interview Survey	
Sampling Method		
Main Questions	General Articles of respondent	➢ Age ➢ Gender

		➢ Location ➢ Education ➢ Career
	Water Situation	➢ Water Source ➢ Average annual cost for agricultural water ➢ Average annual consumption of agricultural water
	Satisfaction to agricultural water from respondent point of view	➢ Level of satisfaction to water quantity ➢ Level of satisfaction on water cost ➢ How does water cost affect the production ➢ Suitable price from respondents point of view ➢ Satisfactory percentage from total income to be deducted as water cost ➢ The actual percentage form total income which is currently deducted as water cost
	Knowledge on Desalination & Effluent Reuse	➢ Awareness level on Desalination and Effluent reuse
	Land availability and potential for improvement	➢ Available cultivated land ➢ Available water quantity ➢ Potential land availability for future development
	Water Quality	➢ Current salinity level of the water source ➢ Acceptance for reusing the treated effluent to bridge the gap between the demand & supply. ➢ Reasons behind the rejection of the reuse of treated effluent ➢ Acceptance for reusing the desalinated water to bridge the gap between the demand & supply. ➢ Acceptance of blended water (brackish & treated effluent) ➢ The reasons behind acceptingthe reuse of treated effluent, brackish or blended water . ➢ Expected side effects for desalination.
	Feasibility of treated effluent reuse and desalinated water	➢ Impact of reusing treated effluent and desalinated water on crops yield in term of quality and quantity. ➢ Satisfaction to the fact that reusing of treated effluent and desalinated brackish water is enough to cover the shortage in agricultural demand.
	Farm management	➢ Type of cultivation ➢ Irrigation method ➢ Existence of Problems in Irrigation system referred to the water quality. ➢ Main obstacles countering the agriculture development in the Jordan Valley.

3.5.1. Objectives of the survey

- Understanding the current agricultural water situation in the Jordan Valley area
- Assessing the satisfaction level to the agricultural water supply in terms of quantity and quality.
- Questions about the current water resources, interruption of water supply, availability of agricultural land and actual water demand.
- Water supply cost; questions about the cost for agricultural water and farmers' affordability to pay.
- Water related practices: questions related to the irrigation methods, types of cultivation, availability of water saving methods and salinity tolerance crops, willingness to pay, the satisfactory price of agricultural water.
- Assessing the farmers acceptance and willingness to use desalinated water and treated effluent
- Defining targets for future awareness activities by analysis of respondents' opinion.

3.5.2. Target

50 persons were selected for interview. Among the fifty, fifteen are from Jericho City, and thirty-five are from surrounding areas of Jericho city (Jericho Governorate).

3.5.3. Sampling Design

For selection of interviewees, the study area was divided into two blocks one is Jericho city area and the second block is the surrounding localities in the Jordan Valley area (Jericho Governorate). The number of interviewees was decided for 2% - 3% of the target group in the study area, Figure (1) below shows the distribution of survey samples.

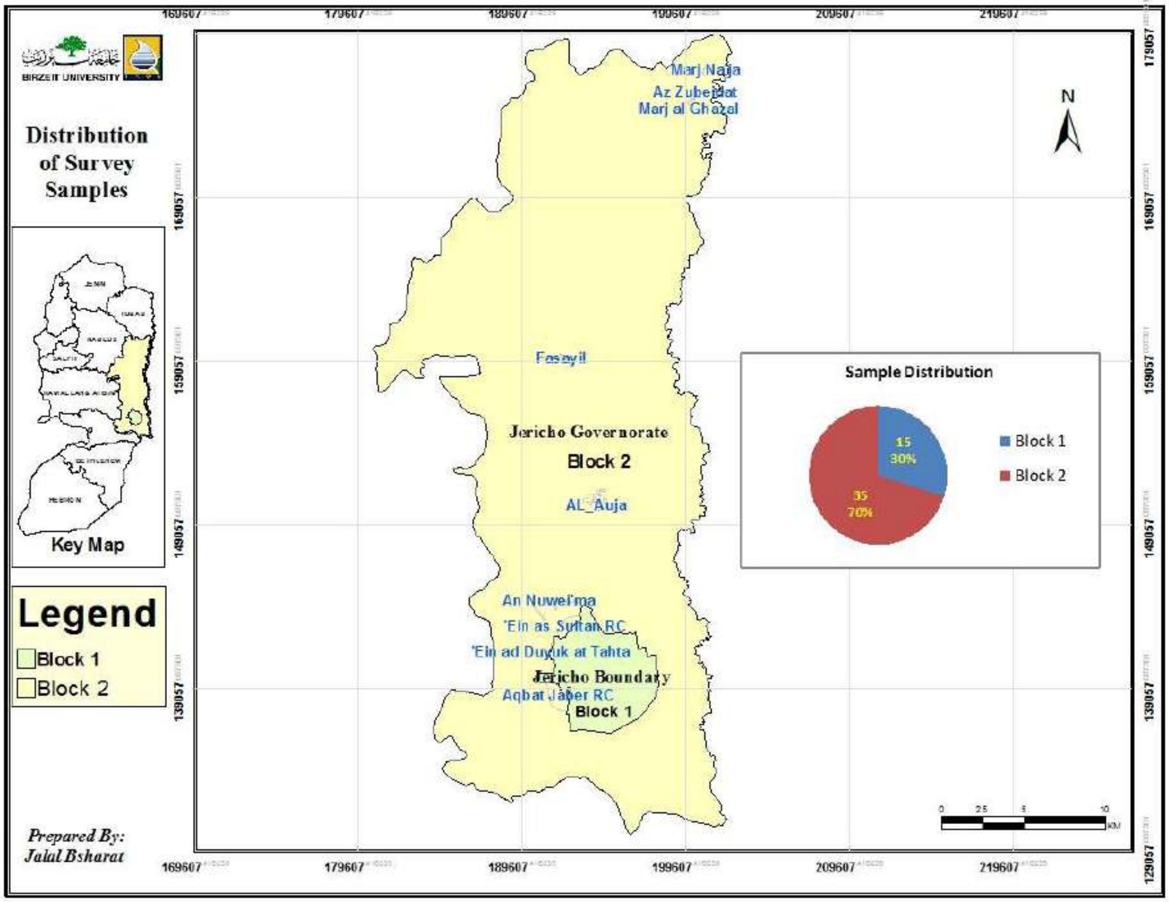

Figure 3: Distribution of survey samples in the study area

3.5.4. Questionnaire:

The questionnaire was written in English to be annexed to the final thesis report and then it was translated to Arabic to suit the level of respondents.

3.5.5. Interview:

The interview was carried out by contacting the target persons directly, respondents were visited at their locations and the questions were read out according to the questionnaire, then the answers of respondents were written down, whereas, some respondents were able to answer the questionnaire themselves and only few samples were sent and collected via emails, particularly the interviews with farmers' associations.

3.5.6. Questionnaire Analysis:

- **General Information (Gender, Age, Education and Career distribution of respondents)**

Table 28 (**Annex 5**) shows that 48 respondents were males and only 2 respondents were females, this is normal due to the nature of the Palestinian community and the social constrains for interviewing the females especially in the Palestinian rural areas. The respondent's age varies between 18 to above 51 years while the majority of the respondents were farmers with education below the Secondary level.

- **Water Supply**

Table 29 (Annex 5) shows that the largest percentage of respondents (76%) supplied through Agricultural wells while the rest (24%) are supplied from springs and other sources. However 64% of respondents answered "Sometimes" to the question if they are satisfied with the water supply.

- **Water cost and Land availability**

As shown in Table 30 (Annex 5), the annual water cost according to the respondents varies between less than 5000 up to 30000 NIS, however 70 % are paying between 5000 to 30000 NIS per year. The water consumption for agricultural purposes varied between 10000 to above 80000 CM/Y whereas 48% of the respondents consume between 21000 to 40000 CMY. Table 3 also shows that 54 % of respondents currently deduct between 10 – 20 % from their total income to cover the cost of Agricultural water whereas 12% deduct more. 74 % of respondents are managing up to 4 ha of agricultural lands and 90 %of respondents have potential land for future development up to 6 ha.

3. 6. Obstacles and constraints

As in any study, the survey entailed a number of obstacles that challenged the progress of the work. The researcher did his best to overcome these obstacles by thoroughly explaining the questions to the stockholders interviewed and crosschecking some of the information provided by asking questions in different manners and by direct observation, the most common obstacles were:

- Limited knowledge about desalination and effluent reuse methods: Many of the farmers encountered throughout the survey had limited knowledge about desalination and wastewater treatment issues, consumption, pricing and other water related information.
- Reduced responsiveness by some people, some farmers were not willing to fully cooperate with the survey and giving information about their agricultural water practices which was problematic.
- Social constrains: The nature of the Palestinian society may be perceived as being somewhat conservative and/or traditional depending on the area and community. In this case, some areas, and thus the researcher couldn't involve so many women in the research.

3. 7. Data analysis

Before beginning the actual data collection from the field, a pilot batch of 10 questionnaires was filled out after which the questionnaire was reviewed and modified based on the comments from the field.

A total of 50 farmers, agricultural associations, and water experts were surveyed. The data was entered into pre-designed spreadsheets after which it was validated by crosschecking 10% of the questionnaires. The data was analyzed later using the Statistical Package for Social Sciences (SPSS).

Chapter 4

4.1. Baseline Data – Assessment of water quantity in the area of study

According to the JICA regional development in the Jordan Rift Valley area (JICA, 2006) there are 19 springs originating from the eastern aquifer and discharge to the eastern slope of the Valley. Total discharge is estimated to be about 42 MCM/Y. The spring water resources are generally located far from the demand areas. There are leakage, seepage and evaporation losses estimated to be about 30% of spring water or 15 MCM/Y.

The Palestinian right of extraction of groundwater from the eastern aquifer is 54 MCM/year, and 78 MCM/Y for further development. The current groundwater extraction from the existing wells is estimated to be about 10-11 MCM/Y. Accordingly, the currently available water resources in Jericho and the Jordan Rift Valley area are assumed as summarized in the following table:

Table 4: Available Water from Eastern Aquifer in Jordan Rift Valley (JICA, 2006)

Water Resources	**Springs (MCM/Y)**	**Wells (MCM/Y)**	**Total (MCM/Y)**
Annual Available Volume	27	10	37

PWA and JICA regional development study estimated that there is a potential of 28 MCM/Y that can be added to the available water resources in the Jordan Rift Valley, This can be available in the short and medium term. They are: (i) Floodwater in Wadi Basins in the Jordan Rift Valley, (ii) Recycled water from wastewater treatments plants in major cities/towns, and (iii) brackish water on the lower terrace of the Jordan Rift Valley, accordingly, 15 MCM of recycled waste water can come from major cities on the central highland in the West Bank, such as Nablus, Ramallah, and East Jerusalem which flows down to the Jordan River basin.(PWA and JICA, 2005),It is expected that about 15 MCM/Y of recycled water might be made available for irrigation

Table 5: Water Demand for the Jordan Valley Area to the year 2015

	Demand MCM/Y	Available MCM/Y	Potential for Development MCM/Y	Deficit
Municipal and Industrial	7.8	27[2]	-	+19.2
Agricultural Water Demand	81[3]	10[2]	15 (recycled Water)+ 28 Flood Water [4]	-28
TOTAL	88.8	37	43	-8.8

Furthermore, the water resources available for domestic and agricultural uses are not better, as only the main 14 communities have access to potable water networks fed by local water resources as in Jericho, or connected to the Israeli Water Company. On the other hand, the Bedouin communities get water through water tankers filled from wells, Israeli Water Company filling points, or springs. The location of these resources affects the cost of transporting water from these interim resources to communities. Figure 1illustrates the location of filling points. The water cost varies between $ 4.28-11.43 (USD) for each cubic meter depending on the traveling distance to community from the well or the water filling point (UNICEF and GVC, 2010)

[2] Total abstraction from wells and springs (PWA and MoA,2010)
[3] Based on PWA and MoA plan to develop the water resources in the Jordan Valley (PWA and MoA, 2010)
[4] JICA study team the Regional Development study for the Jordan Rift Valley (JICA study, 2006)

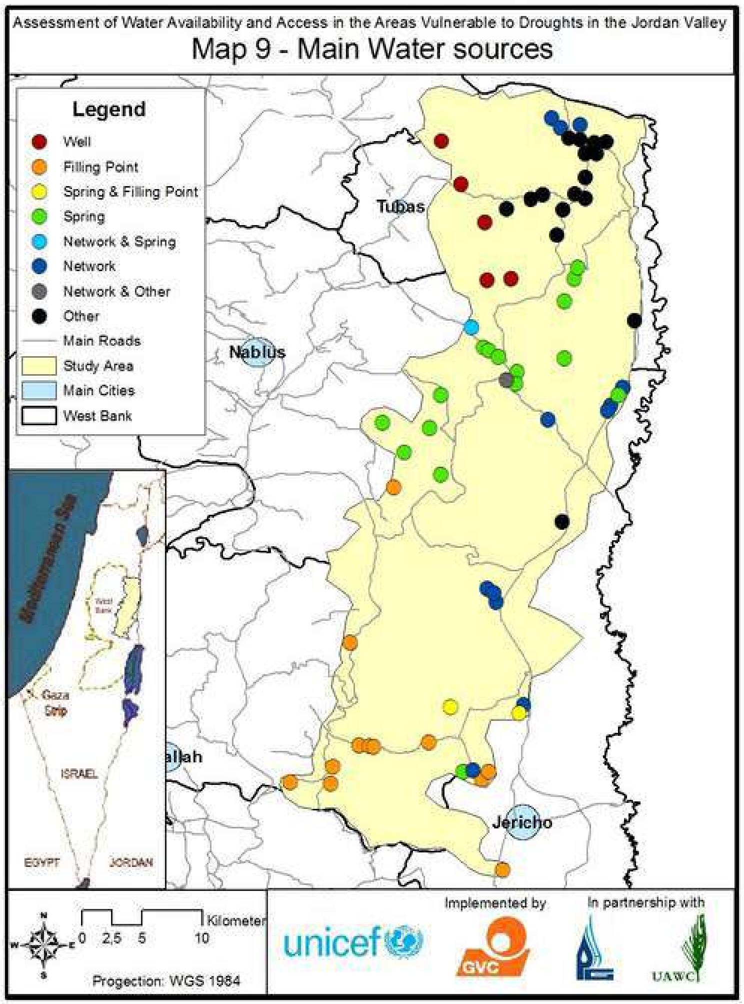

Figure 4: Potable Water Resources Location in the Jordan Valley (UNICEF and GVC, 2010).

For agricultural uses, farmers depend on agricultural shallow wells, **Figure 5,** illustrates the location of the 162 agricultural wells in the Jordan Valley with total abstraction capacity reaching 16.63[5] MCM/Y (PWA, 2011)

Categorization of the wells capacity based on 18 hour operation a day is listed in Table 5.

Table 6: Agricultural Wells Categorization Source (PWA, 2013b)

[5] The total abstraction rate is calculated as a summation of abstraction yearly rate for 121 agricultural well filtered from PWA, 2013 data mentioned before , PWA data is attached in Annex (1)

Categorization Licensed Abstraction (CMH)	No of Wells
Less than 10	42
(10-20)	32
(20-30)	24
(30-40)	9
(40-50)	5
(50-60)	3
(60-70)	2
(more than 70	4
With no record	41

Table 7: Production of Agricultural wells in the Jordan Valley 2009, source: (MoA and PWA, 2010)

No.	Area	Total number of wells	Working wells	Production / 2009
1	Jericho	93	28	1.7
2	DeirHijleh	2	0	0
3	Auja	9	7	0.43
4	Frosh BeitDajan	8	4	0.14
5	WadiFar'a	18	16	4
6	Fasael	1	1	0.06
7	Jeftlik	27	23	2.8
8	Zbeidat	3	2	0.35
9	Marj Na3jeh	13	7	0.8
10	Bardala	8	1	0.09
	TOTAL	**182**	**89**	**10.37**

However, Water quantity derived from the above wells is declining as a result of over extraction and the decline of the annual rainfall (Kubi, 2003).In addition to the restrictions on the rehabilitation of the wells and their apparatuses, agricultural networks are accompanied to the wells to transport water that serves the surrounding agricultural lands(UNICEF and GVC, 2010).

The data analysis provided by PWA for the Jordan valley wells and the analysis provided by (NJS, 2013)show that most of the agricultural wells are of deteriorated quality, and salinity is the major issue of the water quality. Salinity described in Electrical Conductivity maximum EC recorded in 2012 is 6,870 $\mu s/cm^2$, where the minimum was 358 $\mu s/cm^2$ (PWA, 2013a).

The quality deteriorates while heading to the east and the northern east of Jericho and Tubas districts are affected by the salinity of the Jordan Valley aquifer (Marie and Vengosh, 2001).

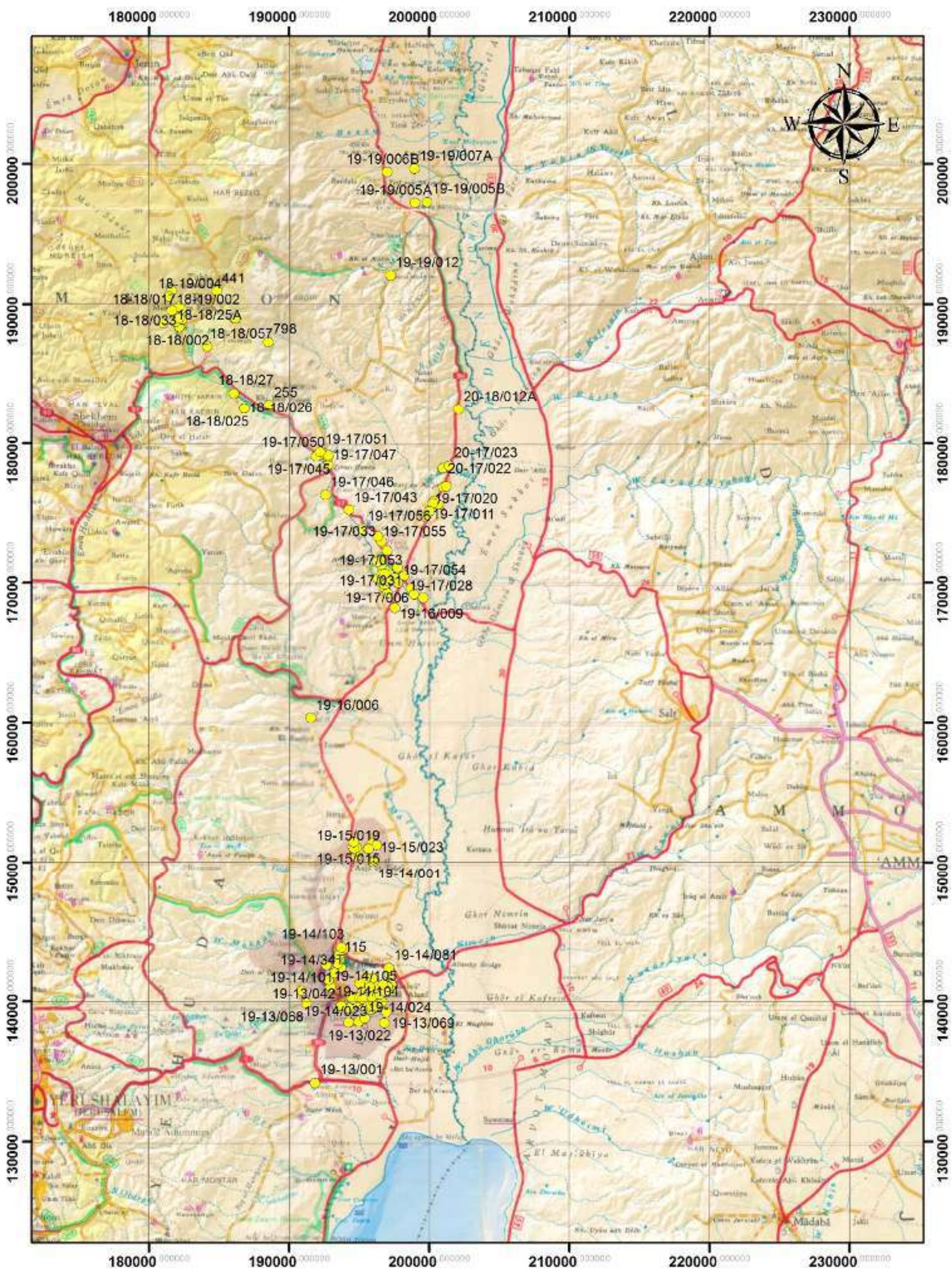

Figure 5: Agricultural Wells Distribution in the Jordan Valley (PWA, 2013b).Desalination in Palestine.

The gap between the supply of freshwater and the demand for water for industrial, agricultural, and domestic use is growing at an alarming rate in Palestine. At the same time, the cost of desalination has come down steadily. Desalination is becoming more affordable and more people can benefit from an almost unlimited resource – seawater in Gaza strip and the good potential of brackish water in the Jordan valley.

According to the PWA annual report for the year 2011, desalination of brackish water is an optimistic option which is still not fully adopted in the West Bank whereas, it has been implemented on a small scale only as an approximate 2-3 MCM/Y of drinking ware, This amount of water is provided through the small scale desalination units that belong to 100 private water vendors in addition to one public sea water desalination plant and around six pubic brackish water desalination plants operated by CMWU and Municipal Departments (PWA, 2011).

The PWA recently finalized a study for water supply. Sea water desalination plant to be constructed in Gaza Strip with a total capacity of 13 MCM/Y, in the long-terms regional seawater desalination plant which will be constructed with a capacity of 55 MCM/Y by the year 2017-2022 (PWA, 2011).

In Palestine, the experience with desalination is new. Deir El Balah in Gaza Strip witnessed constructing the first RO –plant. Municipal water becomes a real problem for the people in Gaza. Therefore, they have started to install RO domestic units to solve their problem. According to policy, the PWA decided to increase the non-conventional water resources through adoption of desalination options (Ismail, 2003).

Water desalination by the technique of reverse osmosis consumes nearly around half of the energy needed for thermal processes. That's why it has proved to be the lowest energy consuming technique according to many studies (Al-Karaghouli A, 2011).

There are some advantages like the modularity of RO units, the simplicity of operation, the compact sizes and lower environmental impacts that make RO units a better choice for water desalination in remote areas. Water desalination by RO units removes inorganic ions, organic materials, viruses and bacteria.(El-Ghonemy, 2013).

Table 8:Palestinian Standards for acceptable level of drinkable water (PWA, 2011).

No.	Parameter	Unit	Value
1	pH		6.5-8.5
2	Turbidity	NTU	□5
3	Carbonate ($CO3^{=}$)	mg/l	□ND
4	Bicarbonate ($HCO\text{-}_3$)	mg/l	□ND
5	Total Dissolved Solids (TDS) at 180^{o} C	□mg/l	□1000
6	Sulphate	mg/l	□200
7	Ammonium	mg/l	□ND
□**8**	Chloride (Cl)	mg/l	□250
9	Nitrate (NO_3)	□mg/l	50
10	Calcium (Ca)	mg/l	100
11	Magnesium (Mg)	mg/l	100
□**12**	Iron (Fe)	mg/l	0.03
13	Manganese (Mn)	mg/l	0.01
14	Sodium (Na)	mg/l	200
15	Potassium (K)	□mg/l	10
16	Total Suspended Solids (TSS) at 105^{o} C	mg/l	ND

4.2.1. Desalination in the West Bank

The increasing levels of salinity in groundwater are a significant sign of water degradation. The alluvial Pleistocene wells in the Jericho area, show high salinity, as well as high susceptibility to contamination (Khayat et al., 2006).

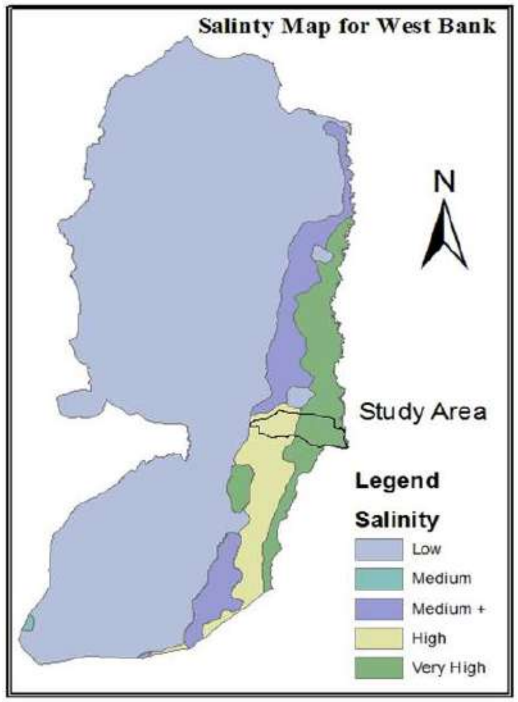

Figure 6: Salinity map for West Bank (PWA, 2012)

The growing demand for both domestic and agricultural use of water in the Jordan valley implies applying a reliable management for all available resources. Water scarcity implies seeking of new unconventional resources and making use of new efficient technologies.

There are several trends for the importance of desalination to provide future answers for water needs in the MENA region and it can be considered as a promising solution.

Unfortunately and contrary to the situation in Gaza Strip, desalination, as a means of water purification, is not widely known in the West Bank. This referred to the fact that the majority of Palestinian communities in the West Bank are relying mainly on mountains aquifers with acceptable water quality.

Other areas in the West Bank are served through the Israeli water company (Mekorot) which controls most of the water resources in Palestine including the brackish water reserve in the Jordan Valley.

In this context, there were several attempts initiated by different actors involved in the water sector to implement new initiatives for water desalination. Most of desalination attempts were based on the RO technology, however, all these attempts were considered as pilot projects for limited extend or for scientific research and experimental purposes.

One of the objectives for this research is to collect general information on these actions and also to provide an initial assessment on their status.

4.2.2. Desalinating Plants in the Jordan Valley

A field survey has been conducted to evaluate the existing desalinated projects in the Jordan valley area; it is found that there are only four small scale R.O units located as shown in Figure 6:

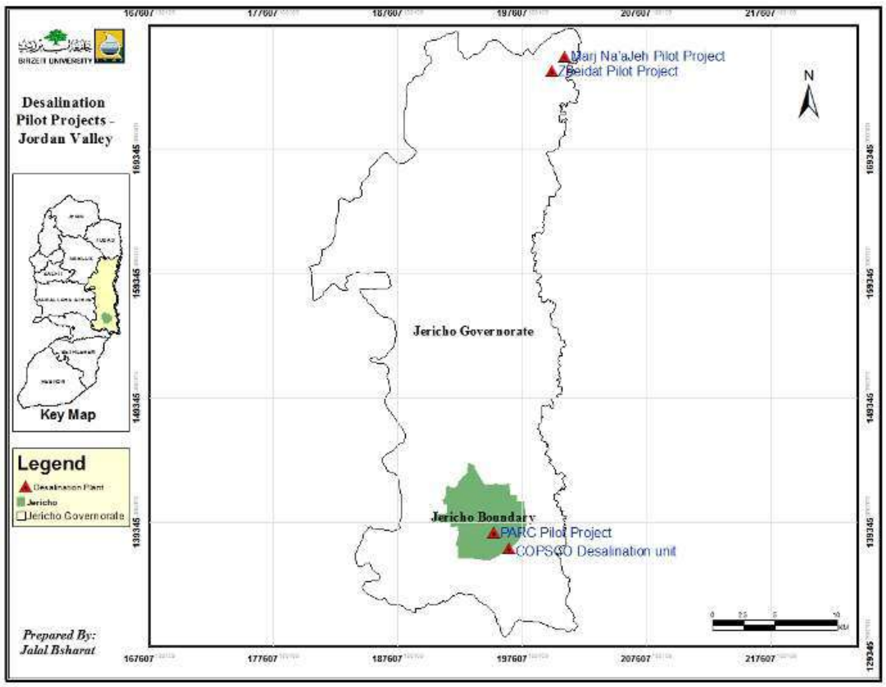

Figure 7: Location map for Desalinating projects in the Jordan Valley modified according to (Jericho-Municipality, 2013).

4.2.3. Desalination pilot project in Zbeidat village for domestic consumption

Figure 8: Zbeidt Pilot Project

As shown in Fig.7, the R.O. unit located in Zbeidat village 35 km north to Jericho city, has been implemented by Al-Najah University in cooperation with local contractor (Global Environment Services - GES) under the supervision of PWA. This project was donated by MEDRC (Shaieb, 2013), Table 8 below shows the quality analysis for the source of water in Zbeidat RO unit .Annex(2), describes the technical data for Zbeidat plant.

Table 9: Quality Parameter's for Feed water (AL-Najah, 2012).

Quality Parameter	Unit	Water Source (Well)	
		Zbaidat Well	Zbaidat Tank
TDS	mg/l	2681	2636
TSS	mg/l	9	10
pH		7.78	7.58
Chloride	mg/l	1200	1200
Sodium	mg/l	473	483
Sulfate	mg/l	166	157
Magnesium	mg/l	158	146
Calcium	mg/l	220	200
Potassium	mg/l	15.5	13.1
Iron	mg/l	0	0
Bicarbonate	mg/l	305	305
Bromide	mg/l	12.4	9.8
Silica	mg/l	26.6	21.6
Boron	mg/l	0.53	0.46
Nitrate	mg/l	37.6	36
Hardness	mg/l as $CaCO_3$	1199	1098
SAR		4.04	6.34
Turbidity	NTU	1.2	1.0
Sediments after week		None	None

Table 10: Quality Parameters for Permeate and concentrate 2011, Source: (Al-Najah University, 2013)

Elements	Concentration (mg/l)		
	Feed	**Permeate**	**concentrate**
Li	0.10	0.00	0.20
Be	0.00	0.00	0.00
B	0.85	0.35	0.50
C	513.45	1.40	431.40
Na	425.90	6.44	776.00
Mg	128.60	0.00	304.55
Al	0.25	0.00	0.00
Si	12.50	0.00	0.00
P	0.65	0.00	1.90
Cl	1462.85	20.90	3403.55
K	30.90	0.38	47.85
Ca	146.50	0.00	200.30
Sc	0.05	0.00	0.00
Ti	0.15	0.00	0.00
V	0.00	0.00	0.05
Cr	0.10	0.00	0.05
Mn	0.00	0.00	0.00
Fe	5.15	0.00	0.00
Co	0.00	0.00	0.00
Ni	0.05	0.00	0.05
Cu	0.10	0.00	0.05
Zn	26.95	0.00	0.40
As	0.00	0.00	0.00
Se	0.00	0.00	0.00
Br	0.00	0.24	12.55
Pb	0.00	0.00	0.00
Cd	0.00	0.00	0.00
Sn	0.00	0.00	0.00
Ba	0.00	0.00	3.20

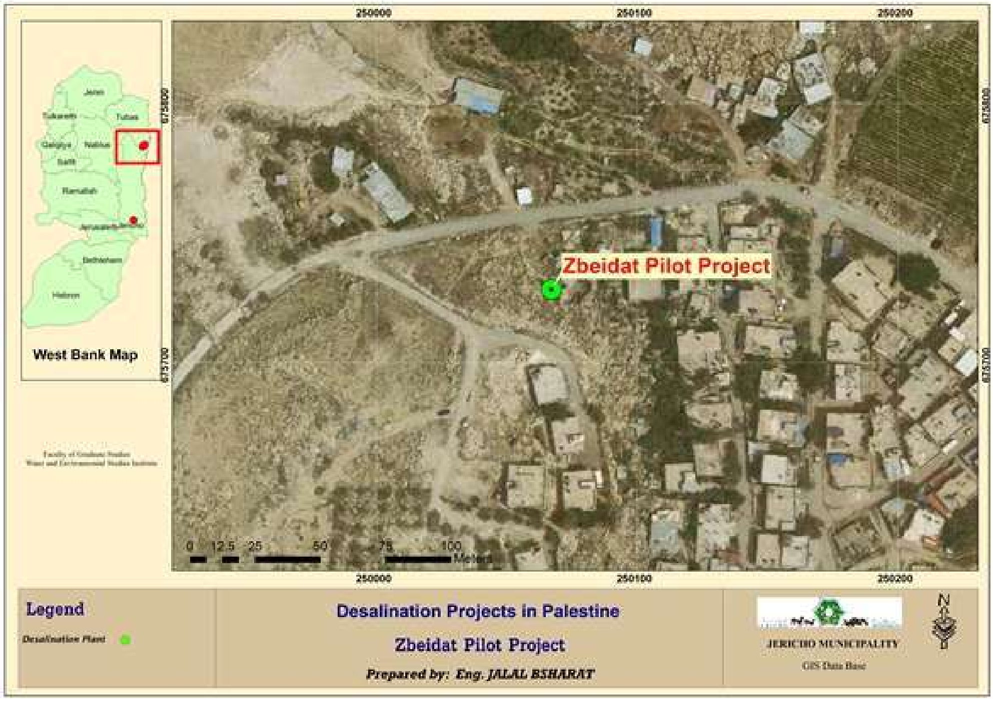

Figure 9: Location of Zbeidat Pilot Project

The desalination unit in Zbeidat is a typical R.O unit with special properties; this unit is totally supplied by a PV power plant.

- Intakes are the structures used to extract source water and transfer it to the process system.
- Pretreatment is removal of suspended solids and control of biological growth, to prepare the source water for further processing.
- Desalination is the process that removes dissolved solids, primarily salts and other inorganic constituents from the water source.
- Post-treatment is the addition of chemicals to the product water to prevent corrosion of downstream infrastructure piping.
- Concentrate management is the handling and disposal or reuse of waste residuals from the desalination system (El-Ghonemy, 2013)

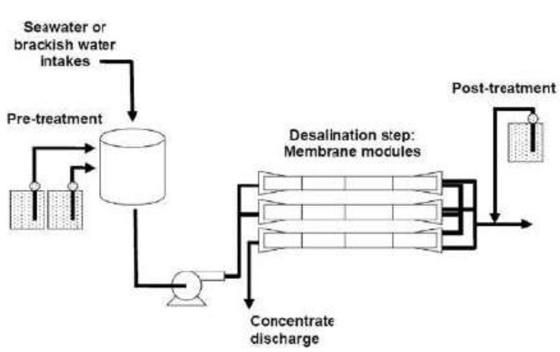

Figure 10: Simple Reverse Osmosis System (El-Ghonemy, 2013).

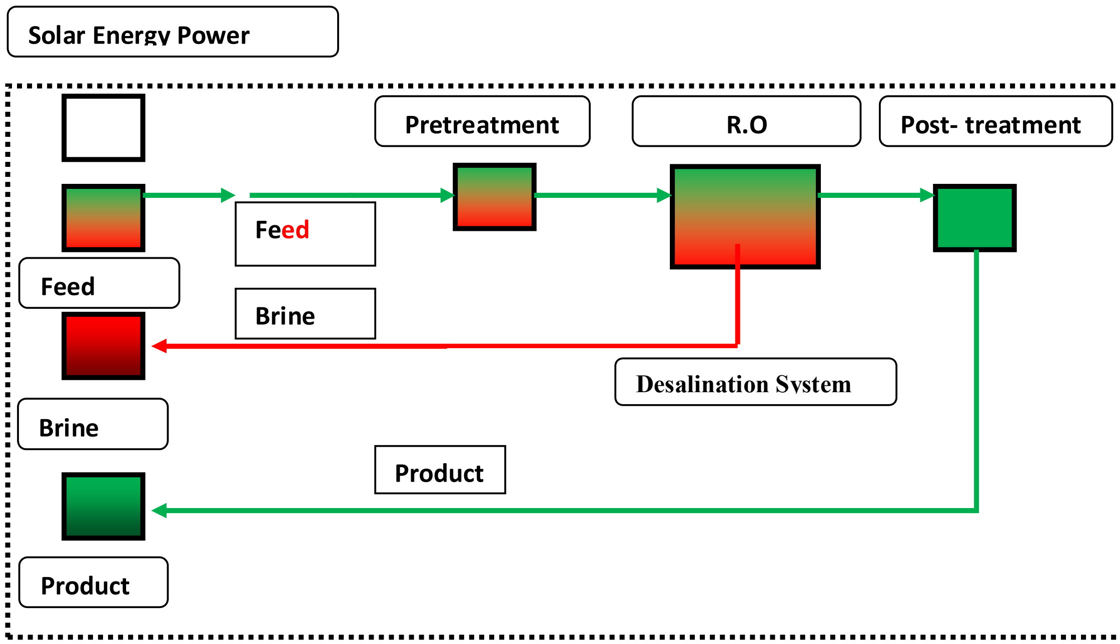

Figure 11: Typical schematic diagram of R.O Desalination System(ADAN, 2011).

Pre-Treatment Unit:

Pretreatment of feed water to the desalination plant is always required to insure trouble – free, reliable operation. The extent, number variety, and size of process unit in the pretreatment depend on the feed water quality and source (open intake, well water, and surface water).

For membrane processes, the major concerns based on (ADAN, 2011) are:

- Suspended solids plugging
- Scaling by metal oxides (FeOH3, MnOH3)
- Scaling by mineral salts (caCO3, CaSO4, BrSO4, SeSO4, CaF2, SiO2)
- Fouling by mineral oil or other organic materials
- Biological fouling
- Membrane degradation by oxidation or other means.

Table 11: Expexted pollutents and their possible treatment processes(ADAN, 2011)

Pollutants	Possible Treatment Processes
Suspended Solids (SS)	Sedimentation, Dissolve Air Flotation (DAF) Granular Media Filters (GMF), Ultra Filtration (UF),Micronics Filters
Colloidal matter	Coagulation and flocculation
Scaling	Scale inhibitors, PH adjustments, softening
Metal Oxides	Pre oxidization and SS Removal
Microbial growth	Pre chlorination, biocides
Dissolve organic matter	Coagulation and flocculation, activated carbon
Oxidizers	Reducing agent

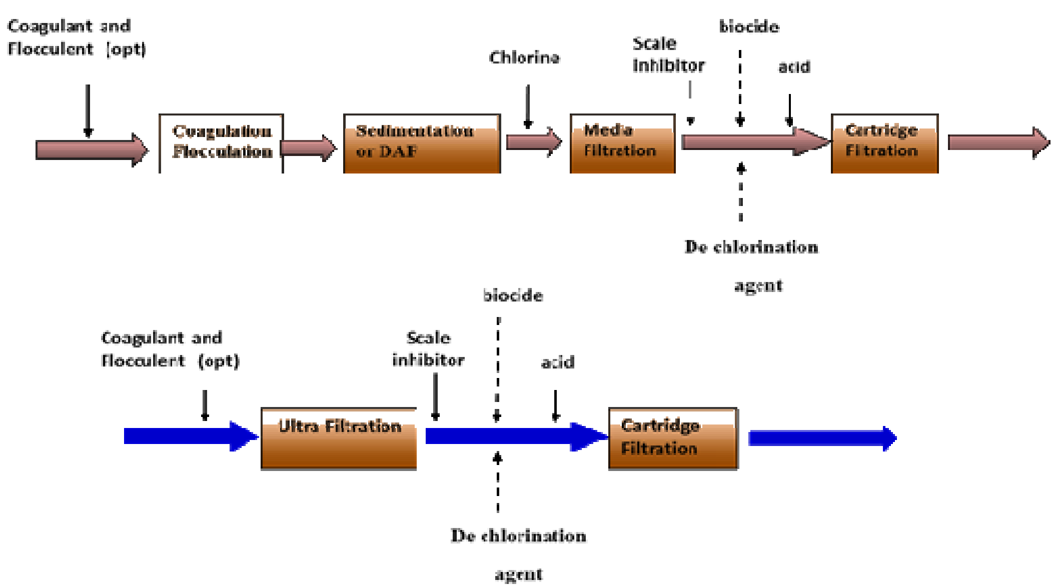

Figure 12: Typical pretreatment possible schemes, Source: (ADAN, 2011).

The Pre - filtration process in Zbeidat unit consists of two stages, the Media filtration and the Cartridge filters.

Figure 13: Pre-filtration unit in Zbeidat desalination plant

R.O unit:

The R.O unit in Zbeidat desalination plant is a two-stage process. The unit consists of three membranes of 4 inch diameter each (two membranes for the first stage and one membrane for the second stage.

Figure 14: R.O unit in Zbeidat desalination plant

Anti-Scaling Unit:

It has been stated by (ADAN, 2011) that without any means of upstream scale inhibition, RO membranes and their flow passages will foul due to scale, the precipitation of sparingly soluble salts. Common examples of scale are calcium carbonate (CaCO3), calcium sulfate (CASO4), barium sulfate (BaSO4), and strontium sulfate (SrSO4). Less common but equally problematic are silica (SiO2) and calcium fluoride (CaF) scales. The unti-scalentunit in Zbeidat desalination Plant consists of

100 liter unti- scalent tank with auxiliary dosing pump injecting the unti-scalent directly to the feeding water pipe.

Figure 15: Unti-scalent unit in Zbeidat desalination plant

Power Supply:

The R.O unit in Zbeidat is supplied through a PV power system of 28 solar modules providing an average 5 kw/hr. The main components of the PV system are:

- **Invertors:** Convert DC power from solar array to AC for use at electrical appliances
- **Cables:** Connect the system component
- **Storage:** Used to store solar – produced electricity for nighttime or emergency use
- **PV Panels:** Collecting solar radiation
- **Controller for battery charging:** Prevents batteries from being over charged
- **Power Switch and Fuse:** Allows power from a PV system to be turned off
- **Mattering:** Measures electrical production and use

Figure 16: PV energy supply system in Zbeidat desalination plant

Produced Water

The desalinated water produced by this unit is used for domestic consumption by nearby houses in the village. It has been estimated that between 6–8 CM of desalinated water are produced every day. The water is blended with saline raw water at (2:1) ratio in order to be normalized and maximize the benefit of this water; the raw water supply for this unit is produced from a local ground well in the area.

Figure 17: Product use in Zbeidat desalination plant

Brine disposal:

The concentrated water (Brine) is discharged to the Agricultural network; however, small scale pilot of salt drying beds has been tested in the site.

4.2.4. Marj Na'jeh desalinating pilot project for agricultural use

The Pilot R.O unit in Marg Na'jeh has been implemented by MoA through a joint fund from the Arab organization for agricultural development and the united nation development pregame (UNDP/ PAPP).

The purpose of this unit is to treat the high salinity brackish water produced from neighboring ground wells to be used for agricultural irrigation, the estimated production of the unit is around 400 cubic meters / day used to irrigate around 30 hectares of agricultural lands planted with vegetables and Legumes.

The total cost of this plant was $150 000 (USD) with an average cost of $ 0.15 (USD) per single cubic meter for operation and maintenance.

The plant is supplied with saline water from a neighboring ground well in the area and the total capacity of the plant is 75 cubic meters / hr with 73 % treatment efficiency, i.e. 20 cubic from the total are rejected as Concentrate and disposed to the Jordan river(Abuelhaija, 2013).

Table 12: Raw water analysis for the influent in Marj Na'jeh desalination pilot project, (Abuelhaija, 2013).

No.	**Parameter**	**Unit**	**Value**
1	EC	ds/m	**7.8**
2	TDS	mg/l	**5000**
□**3**	□pH		**7.□**
4	□Ca	mg/l	□**7.□**
5	Mg	mg/l	□□**.8**
6	□Na	mg/l	□**8□**
7	□K	mg/l	□**8**
8	HCO_3	mg/l	□**7□**
9	□Cl	□mg/l	□**9□□**
10	SO_4	□mg/l	**598**
11	NO_3	mg/l	□□

Location:

As shown in Fig.15, the plant is located near Marj Na'jeh village 36 km north to the Jericho city.

Figure 18: Location of Marj Na'jeh Pilot plan

Pre-filtration unit

The filtration process performed in two stages, sand filtration with automatic backwash and the cartridge filters.

Figure 19: Pre-filtration unit –Marj Na'jeh plant

R.O unit

The R.O unit in Zbeidat desalination plant is a single stage process. This process consists of 8 membranes each of 8 inches diameters (six membranes for the first stage and two membranes for the second stage.

Figure 20: R.O unit –Marj Na'jeh plant

4.2.5. PARC Desalination pilot project for agricultural use

PARC desalination unit is typical to the agricultural RO unit in Marj Na'jeh located 3 Km south east of Jericho city inside the premises of the Palestinian agricultural relief committees (PARC), this unit has been donated by GENERALITT VALENCIANA & FPSC and implemented by the PARC under the project of "Improvement in the management and accesses to water in the north of the Jordan Valley".

The Project's main objective was to desalinate water produced from ground wells, which negatively affects the plants and soil.

Figure 21: Location of PARC desalination pilot plant(Jericho-Municipality, 2013)

Figure 22: PARC R.O Unit

4.2.6. COPSICO desalination unit (Private sector)

As shown in Figure 24 below, the plant is located 5 Km S.E of Jericho and owned by The Private company; Consolidated Palestinian Company (COPSCO).This plant is used for desalinating high salinity water derived from private ground well inside the factory.

The plant has been designed and manufactured by the Turkish company “ARC SU ARTIMA TEKNOLOJILERI” and installed in the early 2013, the capacity of this plant is 15-20 CM/D and the desalinated water produced by this plant is used for domestic, irrigation and also for industrial use.

The total cost of the RO plant is approximately $ 40,000 (USD) and the operational cost has been estimated to 1.6 NIS per single cubic meter of desalinated water.(Huzaibi, 2013).

It is worth mentioning that the COPSCO desalination plant is the latest among all other desalination projects in the Jordan valley, this unit is even more advanced from technical point of view as the unit is fully automated in terms of control, backwash and membrane flushing. There are different chemical dosing units added for:

- Disinfection by Sodium hypo chloride
- pH adjustment acids
- Normalization of Sodium hypo chloride by SMBS
- Anti-scaling chemicals

The only criticism for this plant is the absence of a proper method for brine disposal. The brine is disposed to the nearest wadi and the fear that water might be infiltrated into ground causing degradation in soil and ground water. Table 12 shows the analysis for the Feed water in COPSCO desalination plant while Table 13 compares the water quality for Feed and Permeate.

Figure 23: COPSCO Desalination plant –Jericho

Figure 24: R.O unit at COPSCO desalination plant

Table 13: Raw water analysis for the water source at COPSCO RO unit

No.	Parameter	Unit	Value
1	pH		7.8
2	Turbidity	NTU	1.9
3	Carbonate ($CO3^{=}$)	mg/l	0
4	Bicarbonate ($HCO\text{-}_3$)	mg/l	378
5	Total Dissolved Solids (TDS) at 180^o C	mg/l	1918
6	Sulphate	mg/l	29
7	Ammonium	mg/l	0.04
8	Chloride (Cl)	mg/l	900
9	Nitrate (NO_3)	mg/l	22
10	Calcium (Ca)	mg/l	90
11	Magnesium (Mg)	mg/l	100
12	Iron (Fe)	mg/l	00
13	Manganese (Mn)	mg/l	0.00
14	Sodium (Na)	mg/l	398
15	Potassium (K)	mg/l	96
16	Total Suspended Solids (TSS) at 105^o C	mg/l	20

Table 14: Comparison between Raw and Permeate water analysis

No.	Parameter	Unit	Raw water analysis	Permeate water analysis
CATIONS				
1	Calcium (Ca^{++})	mg/l	120	0.46
2	Magnesium (Mg^{++})	mg/l	162	0.63
3	Sodium (Na^{+})	mg/l	1340	13.06
4	Potassium (K^{+})	mg/l	156	1.60
5	Barium (Ba^{++})	mg/l	--	--
6	Strontium (Sr^{++})	mg/l	--	--
ANIONS				
7	Turbidity	NTU	1.9	--
8	Bicarbonate ($HCO\text{-}_3$)	mg/l	488	62.64
9	Chloride (Cl)	mg/l	3000	3.43
10	Sulphate (SO^{4--})	mg/l	200	0.77
11	Nitrate (NO_3^{-})	mg/l	15	0.24
13	Fluoride (F^{-})	mg/l	0	0
14	Carbonate (CO_3^{--})	mg/l	0	0
	Silica (SiO_2)	mg/l	0	0
Other – little, Organic, etc.				
15	pH		7.2	6.5 – 7.2
16	Total Dissolved Solids (TDS) at 180° C	mg/l	5650	82.84
17	Conductivity	µs/cm	11000	131.2

4.2.7. Cost analysis assumption

The data and assumptions used for calculating the cost are summarized as follows:

- Pumping cost is not included
- Land cost is assumed zero as all lands have been provided by the operators
- Capital cost is taken based on recent offer received supplying company $ 40 000 (USD) against BWRO unit of 50 CM/D capacity(Huzaibi, 2013).
- Annual membrane replacement cost is estimated equalto10%of the membrane purchase cost (El-Dessouky and Ettouney, 2002).

- Membrane purchase cost is estimated equal to 6% of the capital cost (El-Dessouky and Ettouney, 2002).
- The life time is assumed to be 10 years for the existing BWRO under the study.

The other is actual data obtained from plants operation manual.

Table 15: Summary Data for Desalination Plants in the Jordan Valley

Unit	Use	Location	Owner	Treatment method	Treated water quantity CM/D	Capital Cost/$USD	Finance	Date of est.	Power Source	Cost $USD/CM	Brine Disposal
Zbeidat	Domestic	Zbeidat	PWA	RO	15	120,000	MEDRC	2012	On-site PV	0.183[6]	Mixing with Agricultural Water
MarjNa'jeh	Agricultural	MarjNa'jeh	MoA	RO	400[7]	150,000	AOAD &UNDP	2012	Electricity grid	0. 346[7]	Discharged to Jordan River
PARC	Agricultural	Jericho	PARC	RO	400	150,000	GENERALITT VALENCIANA & FPSC	2012	Electricity grid	0.346	Drying pits
COPSCO	Domestic + Agricultural	Jericho	COPSCO	RO	50	40,000	Private Company	2013	Electricity grid	0.44[8]	Discharge to Wadi

[6] As per calculated by (Taha, 2013)
[7] Cost provided by MoA (Abuelheija, 2013).
[8] Source: (Huzaibi, 2013).

4.2. Existing Wastewater Treatment Plant in the Jordan Valley area

Currently, the Jordan Valley has no wastewater collection system instead cesspits are used. Wastewater that does not infiltrate to the groundwater is disposed of in a nearby sewage dump or simply into Wade's surrounding the area. A cesspit with an average volume of 25 cubic meters is usually emptied once every 5 to 6 months. Each tank load costs approximately $ 20 (USD). Currently four sewage tankers are in use in the city alone. The dumpsite is located about 1.5 km east of the nearest residential area. This was the farthest point that could be reached due to the Israeli restriction on land use in the area.

Obviously, no treatment prior to disposal occurs. One existing private treatment plant belonging to Jericho's Casino was receiving small quantity of Jericho wastewater. Jericho Municipality used to discharge all wastewater coming from public facilities and other municipal centers into this medium scale plant. About 250 CM were dumped weekly. Some other small scale wastewater treatment units are available at Jericho hospital, Police academy, Jericho central jail and the residential guard training compound.

However, this is not the present situation. Wastewater quantity and characteristics are currently unknown due to the lack of data especially concerning Jericho. Usually the calculated wastewater generated is based on 70 - 80% of the water consumption, however the case in Jericho may be different due to the large amounts of water that are used in irrigation purposes for air conditioning, home gardens and yards.

4.3. 1. Jericho Wastewater Treatment Plant

In 2010 the PWA received a grant fund from the government of Japan though the international cooperation agency (JICA) to implement the project for the treatment and reuse of wastewater which will be collected by a sewage network expected in the near future.

The works started on the ground in August 2012 for both sewage network and the wastewater treatment plant which is expected to generate 2450 CM/D by the end of 2014 and the discharge will increase gradually until it reaches its maximum capacity of 9900 CM/D by 2025 , the treated effluent is suitable for agricultural use.

Within the framework of this project; one important component of the fund from the Japanese Government implemented through JICA; is the construction of a central WWTP. This WWTP will treat the domestic wastewater of Jericho City in addition to the industrial wastewater from Jericho Agro-industrial Park.

Sewage from both sources should be treated in one site at the eastern plains of Jericho within area (A). The WWTP is located in the middle of the ADS lands of Jericho Agro-Industrial Park (JAIP).

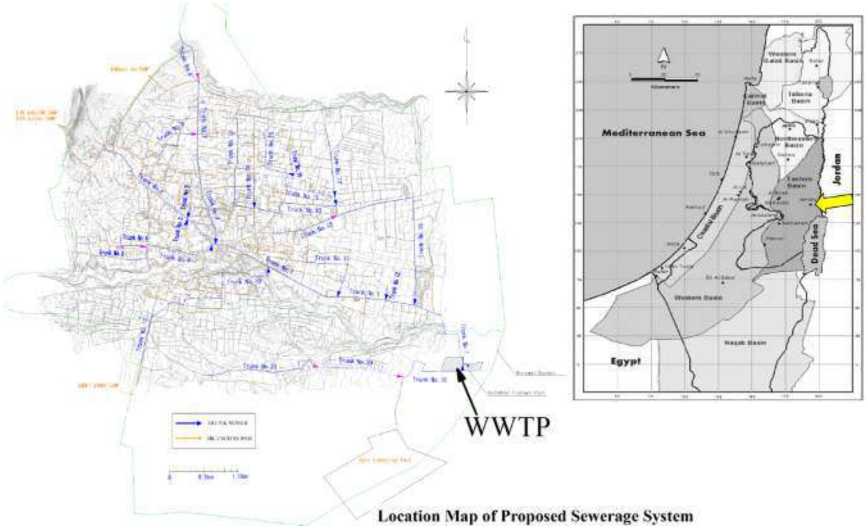

Figure 25: Location Map for JWWTP, Source: (NJS, 2013)

This project, the Jericho wastewater collection treatment and reuse project, aims at the construction of sewerage system in Jericho municipality where no similar system has ever been available. The project improves sanitary conditions and mitigates groundwater contamination which is incurred by wastewater penetration into the ground. The treated wastewater is aimed to be reused as valuable irrigation water. The WWTP is planned to be constructed at an agricultural land located south-east of Jericho Municipality, which has the lowest elevation in Jericho city. The land located in (A) Zone area within Palestinian dominion located next to C Zone, buffer zone to Israel and under Israeli dominion.

Figure 26: JWWTP under construction, 2013

Table 16: Design WWTP Capacity and Treated Wastewater Quality, Source: (NJS, 2013)

Items	Wastewater Amount and Quality			Effluent Quality
	Daily Average	Daily Maximum	Hourly Maximum	
Wastewater Amount (CM/D)	6,600	9,800	19,100	---
BOD(mg/l)	500			20
TSS(mg/l)	500			30
T-N(mg/l)	75			50

Table 17: JWWTP Design, Facilities &Concepts(NJS, 2013)

Facilities and Equipment	**Contents**
Receiving Tank for Vacuum Tanker Truck	To receive wastewater collected by vacuum tanker trucks and remove solid wastes and sand. It comprised screen channel and grit chamber.
Grit Chamber	It is composed of inlet channels, two screen channels and two trains (one for stand-by) of grit collector and a distribution chamber. Manual and auto screens are provided in the screen channel. Sand pumps and a sand separator are equipped with the slave of structure. The settled sand in the receiving tank for vacuum tanker truck is transmitted and also treated by this sand separator.
Reactor, Clarifier	Pollutants contained in wastewater are dissolved and removed. Two trains of the reactor tank with shape of OD tank have retention time exceeding 1 day of daily maximum wastewater amount. Two trains of the circular clarifier have surface load less than 12 m^3/m^2/day.
Chlorine Disinfection Tank	Equipped with the deforming pump, utility pump and weir-type flow meter. Sodium hypochlorite is applied for disinfection.
Gravity Sludge Thickener	The thickened sludge of surplus sludge is transferred to sludge drying beds.
Sludge Drying Bed	Dries thickened surplus sludge. Sludge depth is 30cm and hauled outside of beds after 14 days. Half of planned beds are to be constructed by this project.
Electrical Equipment	The power is received from Jerusalem District Electricity Company (JDECO). The major equipment can be operated by engine-driven generator and by a solar panel with capacity of 100 kW. Return surplus power to power grid. The operation supervision is carried out by monitoring screen connected to computer installed in administration building but basically the facilities shall be manually operated at site.

Table 18:Estimated Wastewater Quantity and Quality from JWWTP, Source (NJS, 2013)

Areas / Year		**2010**	**2015**	**2020**	**2025**	**Ultimate**
Jericho Municipality	Population (P)	25,895	28,792	32,042	35,692	35,800
	C. Population (P)	0	14,396	25,634	32,123	35,800
	C. Ratio (%)	0	50	80	90	100
	WW Volume (m^3/d)	0	2,403	4,291	5,391	6,006
Surrounding Areas	Population (P)	14,088	17,263	20,722	24,466	24,600
	C. Population (P)	0	0	10,361	17,126	24,600
	C. Ratio (%)	0	0	50	70	100
	WW Volume (m^3/d)	0	0	1,067	1,882	2,703
Agro-Industrial Park	Population (P)	0	0.23	100	100	100
	C. Population (P)	0	270	1,180	1,180	1,180
Total	Population (P)	39,983	46,055	52,764	60,158	60,400
	C. Population (P)	0	14,396	35,995	49,249	60,400
	WW Volume (m^3/d)	0	2,673	6,538	8,453	9,889
Average Concentration	BOD	---	342	400	401	408
	TSS	---	392	452	456	466
	T-N	---	64	71	73	76

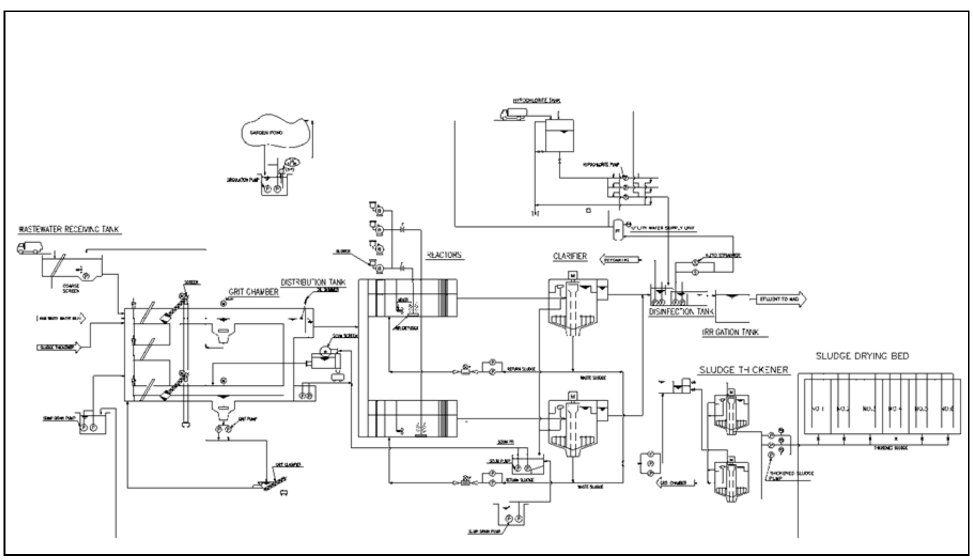

Figure 27 : JWWTP- Treatment Flow Sheet, Source: (NJS, 2013).

Table 19: Estimated annual cost and average cost for treated effluent in JWWTP, (NJS, 2013).

Items				**2014**	**2015**	**2016**	**2017**	**2018**	**Sum**	**Remarks**
O&M Cost	Personnel			262,782	473,013	496,644	521,483	547,554	2,301,476	
		Managers and		82,042	147,676	155,052	162,800	170,944	718,514	
		Technicians and Workers		180,740	325,337	341,592	358,683	376,610	1,582,962	
	Electricity			7,195	203,949	474,428	798,669	1,177,373	2,661,614	
		Fixed Charge		47	85	89	93	98	412	
		Metered		7,148	203,864	474,339	798,576	1,177,275	2,661,202	Solar Deducted
	Repair			0	299,603	665,817	1,406,212	401,790	2,773,422	
	Chemicals			7,323	31,825	58,897	91,134	128,706	317,885	
	Sum		A	277,300	1,008,390	1,695,786	2,817,498	2,255,423	8,054,397	
Capital Cost	Interest			0	0	0	0	0	0	
	Depreciation	0%		0	0	0	0	0	0	
	Sum		B	0	0	0	0	0	0	
O&M and Capital			c=a+b	277,300	1,008,390	1,695,786	2,817,498	2,255,423	8,054,397	
Annual				252,945	813,950	1,434,720	2,113,350	2,844,080	7,459,045	
Cost : $USD /CM				**0.3045**	**0.3441**	**0.3283**	**0.3703**	**0.2203**	**0.2999**	Avg= 0.311

4.3. 2. Wastewater treatment plant in the Intercontinental hotel

The WWTP in the Intercontinental hotel with capacity of 800 CM/D is located in the southern entrance of Jericho. This WWTP serves mainly the hotel and the sewage brought to the site by the sewage tankers from Jericho, the type of treatment is SBR.

The WWTP at Intercontinental hotel is a private property established 1998 and operated by a technical team in the hotel.

The total cost of the WWTP is approximately $ 1.6million (USD), the cost of one cubic meter of reclaimed water estimated to be approximately $ 0.45 (USD) which appears high for the first while but can be justified that the WWTP is not operated at full capacity and also by considering the extra energy consumption required for post treatment.

The reclaimed water used for irrigating 50 ha of Palm trees , landscape trees and green yards surrounding the hotel area while the sludge is collected by seepage trucks and disposed at Jericho dumping site.

Figure 28: WWTP in Jericho Intercontinental Hotel

4.3. 3. Compact units in Jericho district

The small scale (modular units) in Jericho are located in Jericho hospital, Police academy, Residential guard compound and in the Jericho Central Jail, each unit has three chambers which are anoxic zone, extended aeration zone and sedimentation zone. Extended aeration process results in wide band operation regarding permitted concentrations of solids in the aeration tank (2500-5000 mg/l). The efficiency of the system is enhanced by the use of Free-floating Bio-film carrier media.

Each unit consists of aeration tank, settling tank and control room. Each modular unit has different size.

Table 20: Capacity and Design Basis(ARGES, 2013).

Capacity	**150 CM/D**
BOD	500 mg/l
TSS	553 mg/l
Total N	120 mg/l
Total P	13 mg/l
pH	6-9

Table 11: Effluent Water Characteristics, Source: (ARGES, 2013)

	Composite Sample	
	2 hours	**24 hours**
B.O.D.	50 mg/l	20 mg/l
TSS	70 mg/l	20 mg/l
Total N	50 mg/l	20 mg/l
Ph	6-9	6-9

Table 21: Total Power Consumption for Jericho Hospital WWTP (ARGES, 2013).

Equipment	**Installed Power (kW)**	**Absorbed Power (kW)**	**Working Hours**	**Amount**	**Total Power**
Inlet Pumps	1,10	0,88	24	1	21,12
Blowers	5,50	4,40	20	1	88,00
Sand Filter pumps	1,50	1,20	24	1	28,80
Chlorination Pumps	0,06	0,05	20	1	0,96
Effluent Irrigation Pumps	1,10	0,88	24	1	21,12
TOTAL (KW/day)					**160,0**

Table 22: Chemical and Electrical Consumption / Year Source: (ARGES, 2013).

Name	Quantity	Unit Price (EURO)	Monthly (EURO)	Yearly Price (EURO)	Yearly Price $(USD) Rate 1:1.39
Drive Unit Gear Oil (L/year)	1	14	-	14	19.46
Chlorination (L/day)	18,75	0,5	281,25	3375	4.69125
Electrical Consumption	58.400	0,133	-	7767.2	10796.41
Sand (kg/year)	25	1		25	34.75
Cartridge Filters	8	6,6	52,8	634	881.26
	TOTAL			**11815.2**	**11736.57**
	Cost $ (USD) /CM[9]				**0.3**

Figure 29: WWTP in Residential Guard compound

[9] Annual discharge : 150 CMD*365=54750 CM/Y

Figure 30: WWTP in Jericho Hospital

Figure 30: WWTP in the Jericho Central Jail and Police Academy

Table23: Summary Data for WWTP's in the Jordan Valley: Summary Data for WWTP Plants in the Jordan Valley**(ARGES, 2013).**

Station	Location	Owner	Treatment method	Treated water quantity CM/D	Capital Cost/$(USD)	Finance	Date of est.	Power Source	Cost $USD/CM
Jericho WWTP	Jericho	Jericho Municipality	Extended Aeration	2450-9900	18,000,000	Government of JAPAN	2012	PV+ Electricity Grid Network	0.311
Intercontinental Hotel	Jericho	Intercontinental Hotel	Aerated Tanks	800	1.600,000	Private Investment	1998	Electricity Grid Network	0.4
Small scale Modular Units	Jericho	PNA	Extended Aeration	75	130,000	USAID and Canada	2012	Electricity Grid Network	0.3
WWTP at Jericho Hospital	Jericho	MoH	Extended Aeration	150	150,000	ANERA		Electricity Grid Network	0.3

4.3. Case study - Arab development society (ADS)

Arab development society was founded in 1945 to assure the welfare of Palestinian refugees after the British mandate withdrew from Palestine in 1948. The Palestinian nationalist "Mosa Alami" and Arab league economic committee were the biggest supporters of the association. Following the establishment, the ADS engaged project to explore for water by the support of United Nations relief agency (UNRWA). ADS started cultivation in the surrounding lands in order to accommodate, train and educate the Palestinian refugees (Hodgkin and Christian, 1953-1984).

New activities are added to the project; students were trained in vocational skills such as Electrical engineering, weaving, carpenter and metal work. The ADS was significantly damaged during the 1948 and 1967 but managed to recover by the help of Friend Organizations in the United Kingdom and USA (Hodgkin and Christian, 1953-1984).

4.6.1. Arab Development Wells

According to the ADS Chief board Dr. Mohammed Qotob," before 1967, ADS operated 26 wells which have been drilled upon the establishment of the project in the mid-fifties. All wells have produced a good quality of water with acceptable salinity percentage and the surrounded land was cultivated with Citrus and Trees especially in the Northern area of the project lands. However, only small part of the Southern area has been planted because of the high salinity of the soil which reached up to 18000 (µs), which means that these areas were not fully cultivated as no trees or plants can survive or give a good yield when irrigated with this water,(Qotob, 2014).

(Qotob, 2014) has also pointed out that over extraction by Israeli wells in the Western area of Jericho has changed the geological map for the area. Israeli wells were drilled along the catchment and recharge area for the Alluvium shallow wells in Jericho, these wells were drilled to the west of Wadi Qelt and Wadi Nweimeh which are the main Wade's responsible for recharging the Quaternary aquifer in Jericho, consequently, all wells located in the Northern area of the ADS have become totally dry or the water level declined dramatically to a sever level below the level of existing pumps. The average depth of ADS wells were ranging between 50 – 60 m while the water level now is below the 70 – 120 meters below the ground level.

On the other hand, rehabilitating and re-drilling was not efficient because of the small diameter of existing casing. Figure 30 below showing a map for well locations while Table 23 in (annex 6) shows the status and technical data of each well.

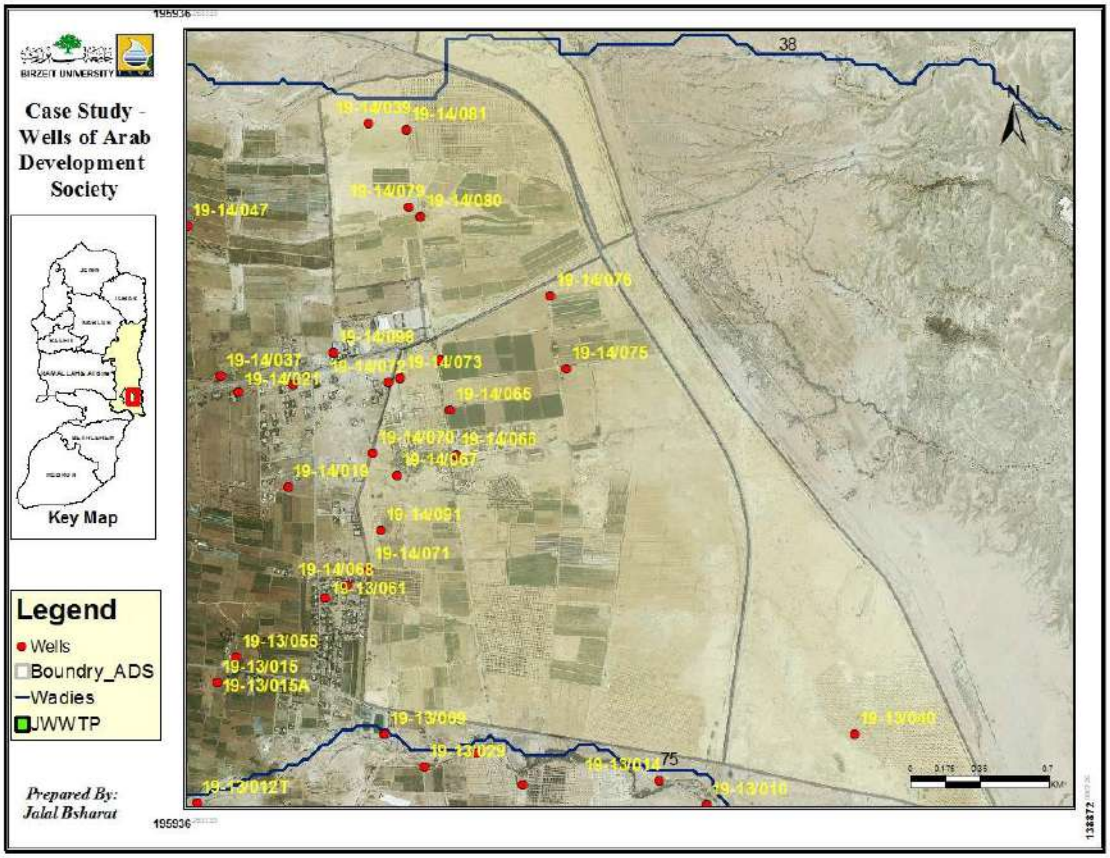

Figure 31: Map for ADS wells, edited according to (PWA, 2013).

The wells which are located in the southern area of the ADS have never been operated since 1967. It is found that the water quality is very bad and the salinity is very high up to 8000 (μs), also it has been concluded that it is more feasible to drill new wells rather than rehabilitating the existing wells because the existing casing is very old and often collapsed during the drilling.

It has been estimated that drilling and equipping of new shallow wells in Jericho area will cost at least $ 162,000 (USD) (Bsharat, 2012).

From total 750 ha owned by the ADS, only 500 ha are permitted by the Israeli's and made available for cultivation and by giving the fact that each hectare will need minimum 10000 – 12000 CM/Y. A minimum 5 – 6 MCM/Y will be needed in order to meet the irrigation requirements for all available lands owned and accessed by ADS.

4.6.2. Water Shortage at Arab Development Society:

The main problems related to the water at Arab development society are:

- High salinity of some wells. TDS ranging from 2000 – 8000 ppm) making this water unsuitable for most of the crops except palm trees and animal fodder which are tolerating water salinity up to 2000 ppm but giving less yield as much as the salinity increased .

- Lack of experience and financial capacity to apply feasible desalination methods or Effluent reuse schemes.

- The difficulty of operating the wells at maximum capacity due to the fact that wells are very old and rehabilitating them is not feasible because of insufficient diameter of the casing, in addition to the shallow depth of the well caused by the accumulation of sediments inside the well and corrosion of the casing.

- The dramatic drop of ground water level from 50 – 60 m to 70 – 120 m which caused the dryness of some wells especially in northern area of the ADS project.

- Some wells are located in area “C” and their permits are already expired since 1967 and the Israeli’s are not renewing the permissions neither giving a permission to rehabilitate or re-drill those wells.

- Lack of reliable and feasible studies of what can be done in minimum cost.

4.6.3. Potential for Development:

- Availability of permission for 26 wells gives the opportunity for renewing these permissions and operating these wells to increase the water production.

- The availability of promising water quantities of brackish water which can be desalinated to improve water resources.

- The availability of low salinity water produced by neighboring wells already supplying some farms inside the ADS, this water can be useful to blend with brackish water and reduce the salinity.

- The location of the ADS which lies between the two main Wadi’s in Jericho (Wadi Qilt and Wadi Nweimeh) with average annual discharge of 6 MCM/Y, this can be considered as an optimistic source of low salinity water that can be collected, stored and used for direct irrigation or blending with brackish water.

- The advantage for the ADS of being close to JWWTP which is located only 570 meter to the South East of ADS area.

Table 24: Land Use at ADS

Location	Area / ha
Historical lands owned by ADS	750
Lands under ADS control (Permitted by the Israeli's)	500
Area located beyond the road 90 (Under Israeli control)	250
Northern Project	200
Southern Project	30
Lands available for ADS use for time being and the potential for future	100
Lands rented by farmers	400

Table 25: Water requirements at ADS

Location	Area / ha	Water Requirements CM/ ha /Y	Total
Lands planted by Palm trees or will be planted in the future	400	12000 (120 trees /ha)	4,800,000
Total lands planted with vegetables	35	7000	245,000
Lands planted with Livestock Fodder	50	3000	150,000
Lands used for housing and public parks	15	10000	150,00
Total requirements for irrigating the total area	**500**		**5,195,000**

The total water quantities available for ADS based on the current data provided by ADS are: 117 CM/H * 18 (Average Operation Hours) = 854100 CM/Y, i.e., the shortage between supply and demand is still 4340900 CM/Y

4.6.4. Potential Water Resources

4.6.4.1. Treated effluent from JWWTP

According to (NJS, 2013), JWWTP will receive wastewater from Jericho city, Jericho Agro-Industrial Park and the surrounding localities (Dyouk , Nweimeh , Aqabat Jabir and Ein-sultan Refugee Camps. The expected quantities of treated Effluent will be as shown in Table 26 Which shows that by 2015, ADS can benefit from 2673 CM/D of treated effluent generated from JWWTP if ADS managed to hold an agreement with Jericho

Municipality for utilizing this water, furthermore, the benefit can be optimized by blending the treated effluent with high salinity brackish water10, which means that in 2015, ADS will be able to increase its agricultural water resources by additional 117077411 CMY. According to (AbuSeb'a, 2014), Jericho Municipality has decided 0,3 NIS as a price for one cubic meter of treated effluent.

Table 26: Estimated quantities of treated effluent generated from JWWTP (NJS, 2013).

Areas / Year		**2010**	**2015**	**2020**	**2025**	**Ultimate**
Total	Population (P)	39,983	46,055	52,764	60,158	60,400
	WW Volume (CM/D)	0	2,673	6,538	8,453	9,889

According to the Palestinian standards for treated wastewater effluent for agricultural purposes, treated wastewater has been classified into four classification: High quality (A), Good quality (B), Medium quality (C) and Low quality (D). Table 27 below indicates the standard specifications for wastewater quality as per decided by PWA and the MoA (MoA and PWA, 2013).

Figure 31 shows a proposed piping system connecting ADS wells to a proposed mixing tank for the purpose of blending brackish water with treated effluent or harvested Wadi Run Off water.

[10]- 1 liter of Brackish water of TDS 5000 ml/l and blended 4 liters of treated effluent from JWWTP of TDS 400 ml/l, the TDS of the final product will be 1080 ml/l (5400 / 5).

[11] - Expected daily discharge of treated effluent from JWWTP is 2673 CMD equal to 975645 CM/Y. This quantity can be increased by fifth when blended with brackish water in ADS.

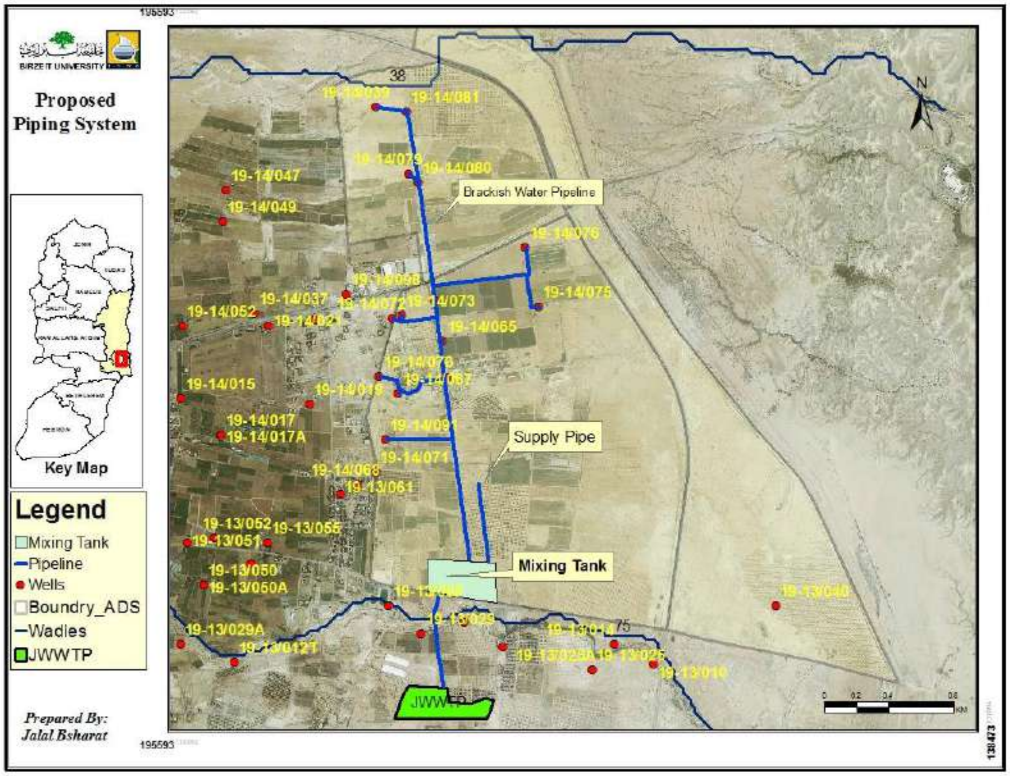

Figure 32: Proposed plan for reusing of treated effluent

Table 27: Wastewater quality standards (MoA & PWA, 2013)

Maximum Limits for chemical and biological properties (mg/l) unless otherwise stated	Quality of treated Wastewater			
	High quality (A)	Good quality (B)	Medium quality (C)	Low quality (D)
Water Oxygen uptake BOD5	20	20	40	60
Total suspended solids TSS	30	30	50	90
Fecal coliform bacteria (colony/100 ml)	200	1000	1000	1000
Chemically absorbed Oxygen COD	50	50	100	150
Dissolved Oxygen DO	Less than 1	Less than 1	Less than 1	Less than 1
Total dissolved solids TDS	1200	1500	1500	1000
Power of Hydrogen PH	9_6	9_6	9_6	9_6
Fat, Oil and Grease	5	5	5	5
Phenol	0.002	0.002	0.002	0.002
Detergents MBAS	15	15	15	25
Nitrate -Nitrogen No3_N	20	20	30	40
Ammonium _ Nitrogen NH4_N	5	5	10	15
Total nitrogen Total _ N	30	30	45	60
Chloride Cl	400	400	400	400
Sulfate SO4	300	300	300	300
Sodium Na	200	200	200	200
Magnesium Mg	60	60	60	60
Calcium Ca	300	300	300	300
Sodium adsorption ratio SAR	5.83	5.83	5.83	5.83

Phosphate Phosphorus PO4_P	30	30	30	30
Aluminum Al	5	5	5	5
Arsenic As	0.1	0.1	0.1	0.1
Copper Cu	0.2	0.2	0.2	0.2
Fe	5	5	5	5
Manganese Mn	0.2	0.2	0.2	0.2
Nickel Ni	0.2	0.2	0.2	0.2
Lead Pb	0.2	0.2	0.2	0.2
Selenium Se	0.02	0.02	0.02	0.02
Cadmium Cd	0.01	0.01	0.01	0.01
Zinc Zn	2	2	2	2
Cyanide CN	0.05	0.05	0.05	0.05
Chrome Cr	0.1	0.1	0.1	0.1
Mercury Hg	0.001	0.001	0.001	0.001
Cobalt Co	0.05	0.05	0.05	0.05
Boron B	0.7	0.7	0.7	0.7
Bacteria E.coli (Colony /100 ml)	0010	0100	0100	0100
Nematodes (Eggs/L)	Less than or equal 1	Less than or equal 1	Less than or equal 1	Less than or equal 1

4.6.4.2. Run off harvesting and the possibility for artificial recharge and blending with brackish water

The scarce water situation in the Palestinian territories implies seeking of new water resources. Storm Water Harvesting (SWH) can be considered as a reliable management technique for collecting, storing and distributing the flash floodwater of the major wadi's during the winter seasons. This technique will increase water storage of groundwater aquifers and provide additional quantities of water for agricultural sector during the dry and high-water demand in the summer seasons.

Flashing and intense rainfall events over the western highlands of the Jordan Valley can lead to short term surface water availability, without a proper management of this significant water resource, the excess rainfall can be quickly lost due to the high evaporative environment and loss from the watershed via runoff without any proper benefit (PWA, 2012).

Figure 33: Major wadi basins in the study Area (PWA, 2013).

Therefore, this technique can be implemented in one of the major wade's in the Jordan Valley. Wadi El-Qilt and Wadi Newimeh are the most important wade's in Jericho area stretching from mountain region in the west and passing the middle part of Jericho area to the Jordan River and Dead Sea in the east. ADS lands are luckily located between both Wadis which are attached to the north and east borders.

An optimistic quantity of flood water ranges from 3.0 to 10.0 MCM flows in both Wadis during 3 months of a rainy season (from Dec to Feb). This quantity of water can be utilized to improve the water resources and the quality of Quaternary Aquifer and will also provide additional water for agricultural development in Jericho area. The ADS area is highly recommended to implement such project, since it is characterized by intensive agricultural activities and most of the wells are exploited.

Moreover, several previous studies were carried out in several locations of the West Bank in order to identify the most potential wade's for artificial recharge; Wadi El-Qilt was selected to be the most favorable and suitable location for recharging groundwater in Jericho area (PWA, 2012).

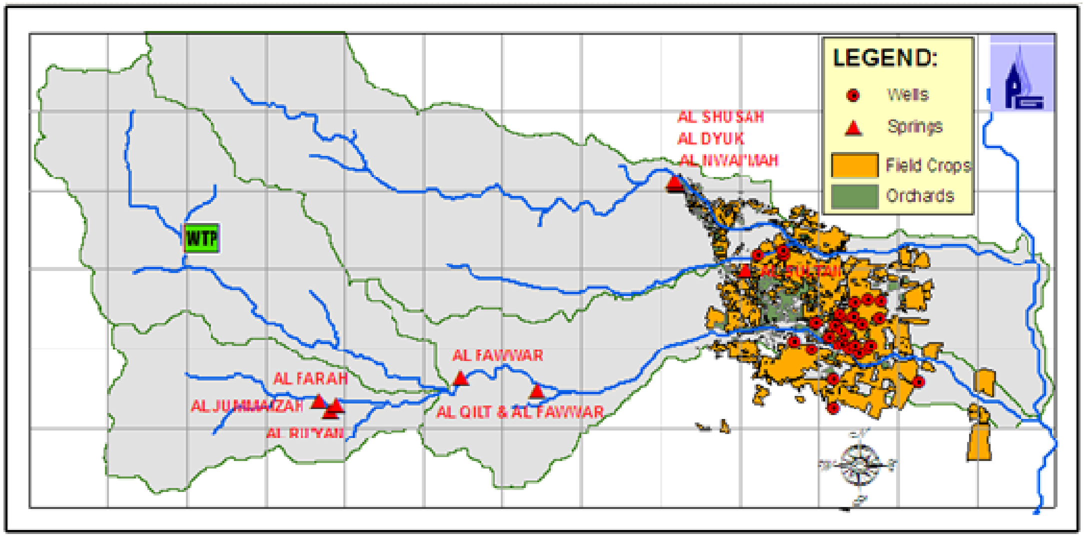

Figure 34: Map for the catchment area of Jericho Wadi's

Table 28: PWA measurment in Wadi Qelt

(1) Extracted from the 1998 FORMARD Report

No.	Date	Time of Measurement (m³/sec)	Flood Discharge (m³/sec)	Flow area (m²)	Mean Velocity (m/sec)
1	Jan. 19, 1974	10:40	3.08	2.15	1.44
2	- do -	12:30	3.99	3.02	1.32
3	- do -	13:40	4.02	2.81	1.43
4	Jan. 21, 1974	10:00	16.02	6.16	2.60
5	- do -	11:20	21.28	7.07	3.01
6	- do -	12:55	30.28	10.64	2.85
7	- do -	13:40	33.77	11.21	3.01
8	Jan. 22, 1974	9:15	9.79	4.32	2.27
9	Mar. 03, 1974	11:05	3.81	2.85	1.34
10	Mar. 04, 1980	12:00	2.78	2.74	1.01
11	Jan. 16, 1992	14:10	1.93	2.67	0.72
12	Feb. 18, 1992	14:45	2.51	2.74	0.92

Data Souece: The 1998 FORWARD's Report

No.	Date	Flood Discharge Measured (m³/sec)
1	Apr. 18, 1971	0.89
2	Jan. 18, 1973	0.71
3	Mar. 03, 1980	2.36
4	Feb. 15, 1987	11.30
5	Feb. 03, 1988	18.11
6	Feb. 01, 1988	3.90
7	Dec. 02, 1991	6.48
8	Dec. 15, 1991	2.88
9	Jan. 07, 1992	7.60
10	- do - (after 4 hours)	8.81
11	Jan. 16, 1992	1.93
12	Jan. 25, 1992	1.93
13	Feb. 18, 1992	2.51
14	Feb. 06, 1992	18.48
15	Mar. 02, 1992	10.18
16	Dec. 20, 1992	17.45
17	Jan. 11, 1993	28.77
18	Jan. 11, 1993	15.21
19	Dec. 17, 1992	17.45
20	Nov. 24, 1994	1.40
21	- do - (after 3.5 hours)	5.29
22	Dec. 30, 1994	4.67

Data Source: PWA

The overall goal of the proposed scheme is to bridge the gap between water supply and demand in Jericho area and minimizes the adverse impact of water shortage during the dry-summer seasons by integrating the brackish water treatment with flash floodwater harvesting from Wadi Qilt during the winter seasons. The main objectives of the proposed scheme can be set as follows:

- Harvesting the flash floodwater in Wadi El-Qilt and preventing this water from being wasted by discharging to Jordan River or over the lands without any real benefit.

- By creating such interventions to collect, store and recharge the flash flood water to the aquifer, this will help in lowering the velocity of the flow and reduce the effects of soil erosions on both Wadi embankments.
- Increasing the potentiality of Quaternary Aquifer and minimizing the decline in the water level and salinity of this aquifer
- Providing additional suitable water for agricultural purposes, this project will increase water supply for agricultural sector and recreation areas in Jericho area
- Improving and developing the integrated management of surface and ground water resources for future perspectives.

Water Harvesting Ponds

- Water harvesting ponds is the most feasible technique for flood water harvesting that can be applied in the Jordan valley, pond realization shall consider the difficulties of estimating the discharge volume of the wadi, the concentration of suspended load that can cause reduction of a storage volume, the kind of intake facility to bring water to the pond and the land availability problems.
- The scope of work will comprise data collection and engineering designs necessary to implement the proposed harvesting technique in Wadi El-Qilt while the expected outcomes can be summarized as follows:
- Water available for agriculture in Jericho will be increased
- Social and economic life will be improved
- Agricultural water purchasing price will be decreased
- Health and sanitation conditions will be improved
- Institutional set up for proper water distribution management will be established, and therefore local water management will be developed and improved

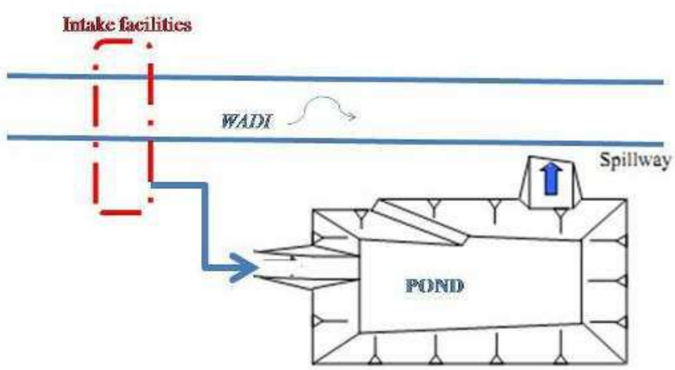

Figure 35: Schematic Diagram for a proposed Flood Water Harvesting Ponds, Source:(Ridini et al., 2013).

4.6.4.3. Installation of small scale Desalination Unit for the ADS

The tables below are evaluating the feasibility of installing a BWRO to desalinate the brackish water from ADS wells

Table 28: Cost parameters for installation BWRO

Operating cost parameter	**Direct** Energy, operation and maintenance man manpower, equipment's and parts replacement, chemical and other consumables
	Indirect Site lease or rent, Insurance, other overheads, Taxes and levies
Fixed costs parameters	**Capital recovery** Manpower ,part of equipment and part replacement, part of chemicals, site lease or rent , insurances, other overheads ,axes and levies
Variable costs parameters	Energy , most of equipment and parts replacements, most of chemicals
Main factors affecting costs	• Feed and product water qualities and process selection • Plant capacity – economy of scale • Local project cost financing, energy , etc) • Site specific conditions and their effect on infrastructure costs (raw water supply, brine disposal, energy supply product removal, etc.) • Method of bidding and contracting, level of competition and contractors profit margins

Table 29: BWRO key techno-economic parameters (ADAN, 2011)

Parameter	**Units**	**BWRO**
Membrane specific fluxes	$l/m^2/h/bar$	20 - 27
Membrane salt rejections	%	98.0 – 99.7
Plant operating pressures	Bar	10 -20
Membrane elements outputs 8-inch element 16-inch element	CM/D	40-48 80-96
Membrane element costs 8-inch element 16-inch element	$ (USD)	400 – 550 1,500 – 2,100
Guaranteed membrane lifetime	Years	6-7
Pressure vessels 8-inch element	$ (USD)	1,150 – 1,450 4,000 – 6,000

16-inch element		
High pressure pump costs	$ (USD)	30,000[12]
Specific energy requirement	Kwh/m^3	0.7 – 1.5 ($0.09 – 0.19 (USD))[13]

Table 30: BWRO plants specific investment (ADAN, 2011)

Item	$ (USD) / m^3/day	% of Total
Site civil engineering works	30 – 50	5 - 7
Feed water supply subsystem	50 – 10	10-30
Product storage and delivery subsystem	10 – 50	2-10
Brine discharge subsystem	50- 180	10-30
Energy supply and distribution subsystem	20-35	4-5
Feed water pretreatment subsystem	25-100	5-15
Desalination units(s), including control and instrumentation	200- 280	35-45
Product post-treatment subsystem	15-35	3-5
Auxiliary subsystems	10-25	2-4
Total tangible or "hard " costs	**410-580**	**75-85**
Engineering	25-45	5-7
Project management, administration & oversight	15-40	3-6
Permitting, legal, financing and other project development costs	35-70	7-10
Insurance and interest during construction	10-25	2-4
Total intangible or "soft" cost	**85-150**	**15-35**
Total project cost	**500 - 700**	**100**

Table 31: BWRO plants total water costs

Item	$ (USD) / m^3	% of Total
Capital costs @7.5 average financing costs, 20 years amortization period, 96% annual utilization and no planed residual value	16-20	39-59
Operating costs Energy @ $0.19 (USD)/ Kwh O&M manpower @ $ 50,000 (USD)/man-year Equipment and parts replacement including membranes Chemicals and other consumables Site lease or rent , insurance, taxes Other overheads **Total operating costs**	14-25	41-61
Total water cost	**30 – 45**	**100**

[12] 100 CMH @ 20 bar selected from Grundfos catalogue
[13] Calculated based JEDCO commercial electricity tariff $ 0.13 (USD)/ Kw

Solar PVs application in Palestine is encouraged not only due the high potential solar energy in Palestine, where the sun hours exceed 3,000 hour per year with average penetration factor 5.4 KW per meter square. But also to the execution of Palestinian Renewable Energy strategy which aims to produce 130 MW of renewable resources by 2020, 50% is called from solar sources, mainly PV (Consortium MVV decon, ENEA, RTE, 2013) (RCREEE, 2013) empowered by the government exemption of the added value tax on RE equipment's (RCREEE, 2013).

Chapter 5

5.1. Discussion and Results

The research highlighted the current agricultural water issues in the Jordan Valley, and tried to explore new feasible alternatives for brackish water desalination in order to utilize abundant brackish water in the Jordan Valley.

To lower the cost, RO was combined with other alternatives such as utilizing the grid off solar PV, blending the brackish water with treated effluent or flood water harvested from Wade’s run-off.

It has been proved that blending brackish water with treated effluent is a feasible alternative by considering the fact that JWWTP will generate 3.5MCM/Y when operated at ultimate capacity and this alternative can be optimized to include other areas in the Jordan when additional 15 MCM/Y conveyed to the Jordan valley from other cities.

The research recommended RO-PV as replication of published studies recommendations and the results of RO projects in Palestine. RO-PV is recommended for its market availability and economic feasibility of energy cost. Coupling RO to the off-grid solar PV lowered the cost to an average $ 0.183(USD)/CM for the Zbeidt desalination unit compared to $ 0.346 USD/CM for Marj Na'ajeh RO unit supplied though the Electricity grid network. The average cost of desalinated water would still be cheaper if brackish water treatment combined with other alternatives such as blending with treated effluent or harvested run off.

Table 32: Comparison between disfferent alternatives to utilize brackish water at ADS

Alternative	Capital Cost $ (USD)	O&M Cost $(USD) / M^3	Total production CM/H	Advantages	Potential for land development (ha)	Constrains
Small scale BWRO unit Power supply " Electricity Grid "	70000	0.346	**100**	Market availability Simplicity of maintenance and operating. High quality water	**73**[14]	Economic and Environmental constrains High Energy consumption Required Brine treatment Loss of nutrients and minerals required for agriculture.
RO coupled to the off-grid solar PV	160 000[15]	0.183	**100**	Low cost, Low energy consumption High quality water Green energy and low carbon emissions	**73**[14]	High capital cost Limited performance in winter Space required for PV plant
Brackish water blended with treated effluent	120 000[16]	0.23[17]	**100**	Low cost, Low energy consumption Good quality Advantage of Nutrients and minerals in the treated effluent	**73**[14]	Land required for mixing tank Pre-treatment will be required Sensitivity to the annual rain fall
Brackish water blended with harvested run off.	140 000[18]	0.25[19]	**100**	Low cost, Low energy consumption	**73**[14]	

[14] The calculations are based on Palm trees water requirements of 12000 CM/Y/ha ((100 CM/H*24 Hr*365 day)/12000 CM/Y)

[15] Cost calculated based on an existing working plant in Marj Na'jeh (MOA, 2013); including the proposal of replacement of RO- Diesel with RO-PV system. The capital cost of the desalination unit 160,000 USD is inclusive of the desalination unit (2 tanks), storage of brackish water with capacity 150 m^3, storage of treated water with capacity 250 m^3, two pump (75HP), and brine disposal pipe of length 2.5 km.

[16] (Construction of 10 000 CM earth pool to be used as a mixing tank $ 78,000 (USD + Pump station 100 CM/H and pipeline $ 40,000 (USD) details in (Annex 7)

[17] The price for 1 M^3 of treated effluent from JWWTP is (USD) 0.09 + pumping cost from JWWTP to the mixing tank in ADS premises

[18] Cost details (Construction of 10 000 CM earth pool to be used as a mixing tank $ 78,000 (USD) + Pre-filtration unit 400 CMH $ 20,000 (USD) + Pump station 100 CMH $ 40,000 (USD) details in (Annex x)

[19] The cost of 1 M^3 of brackish blended with harvested run off is $ 0.25 (USD) which includes (Pumping of brackish water to the mixing tank + pre-filtration for harvested run off + pumping cost from to the mixing tank to the internal network in ADS premises (costs are detailed in annex 6)

5.2. Questionnaire Results

5.2.1. Satisfaction to Agricultural water cost

Table 31 (Annex 6): shows that 42% of respondents consider that the cost for Agricultural water is high and of significant effects on the production (56%), while 10 % has considered the cost as Very high, whereas 62% of respondents believe that water cost shouldn't exceed 10% of the total income and 68% believe that price for one cubic meter should be between 0.2 to 0.4 NIS.

5.2.2. Satisfaction to the Water Quality

As shown in Table 32 (Annex 6), only 14 % of respondents receive agricultural water of low salinity (Less than 1000 ppm) while (56%) are supplied with brackish water of medium salinity (1000 – 3000 ppm) and the rest of respondents (30 %) are supplied with moderately high salinity water of more than 3000 ppm. However the response shows that the majority of respondents have experienced scaling problems in their water networks but, less than 16% had problems of suspended solids or turbidity problems.

5.2.3. Respondents Awareness and Willingness to accept the use of Desalinated water and Treated Effluent

In Table 33 (Annex 6), 56% of respondents responded negatively to the question about their awareness or knowledge on desalination and effluent Reuse while only 44% has shown good to very good knowledge in this regard. However, it was very clear that the majority of respondents are against the reuse of treated effluent (48% gave the answer No and 24% were extremely against). The main reasons behind the rejection of treated effluent were related to health concerns (40%) and quality concerns (28%), however, their opinion has been changed to the use of Blended water (brackish water and treated effluent) as 58% were positive to the use of Blended water.

Contrary to the response to the reuse of Treated Effluent, 94% positively responded to the use of desalinated water. The reasons behind the positive response to the use of desalinated and blended water vary between economic considerations, water shortage and Environmental aspects; furthermore, 72% of respondents believe that the reuse of desalinated water and treated effluent is enough to bridge the gap between the demand and supply for agricultural water.

5.2.4. Farm management

The purpose of this section is to understand and assess the respondents management of their farms in terms of cultivation type, irrigation method and the potential lands available for future development, From Table 34 (Annex 6) it is found that vegetables represent 66% of the cultivated land according to the respondents answers , while the rest 33 % are distributed between citrus, palm trees, animal fodder and other crops, the results have also shown that all the respondents are applying the drip irrigation method in their farms.

The respondents considered that the main problem facing agriculture in the Jordan Valley is marketing (34%) and water shortage (30%) while less importance was given to the cost and supervision. Respondents concerns about applying the desalination technology vary between cost (38%), increasing soil salinity (22%); whereas less importance has been given to water loss as brine.

5.3. Conclusion

From humanitarian and environmental perspectives, Palestine faces sever water challenges pertinent to accessibility, institutional and water management. This research underlines the importance of the brackish water desalination and the use of reclaimed effluent in Jericho district as additional unconventional water sources for agricultural irrigation and drinking water purposes. Currently, the RO desalination of brackish water is the most commonly used technology in Palestine. Due to political reasons and signed water treaty, Israel limits digging new groundwater wells in Jericho district, thus preventing the expansion of agricultural production in the West Bank, and impedes the import of desalination systems or provision of electrical power needed for the operation of large desalination plants.

This has concluded that the most feasible desalination technology is the RO-PV; this has been also proved by different published studies and the results of implemented projects in Palestine. However, R.O technology is still considered as an expensive solution to be tackled by low-income farmers in the Jordan Valley. Therefore, another alternatives has been proposed to alleviate the high cost of desalination to a reasonable level suitable for normal farmers and small agricultural enterprises.

The research favored the use of Reverse Osmosis technology coupled with Solar Photovoltaic as a solution for treating brackish water to overcome the current water and energy issues in the Jordan Valley.

The method and the cost of brine disposal, the farmers acceptance to pay for the off-grid Solar PV's if the government hasn't supported such projects, and also evaluating the governmental strategies in water and energy in order to support similar projects implementation, In addition to introducing the farmers to the benefit of the RO-PV.

The following conclusions also emerged from this study:

- Integrated scheme combining desalination of brackish water with effluent reuse and flood Run Off would be one of the most suitable solutions to improve the water resources in the Jordan Valley and bridge the gap between supply and demand.

- Water scarcity in many countries has brought about significant progress in the use of non-conventional resources (desalination and effluent reuse).

- Jordan and Israel experience has demonstrated that even desalination cost is still expensive but it can be considered as feasible alternative and can be incorporated in overall production costs (even for private initiatives)

- Cost of desalination of brackish water can be competitive but can't be assumed by all the end-users, even the agricultural industry.

- Desalination of inland brackish water raises problems even not well solved due to the brine discharges or brine disposal, and it's necessary to research more about this important topic

5.4. Recommendations

- The cost of desalinated water and treated effluent is still high to be handled by the farmers; this implies investigating new alternatives to support farmers and empowers their affordability.

- The desalination technology needs a comprehensive management system, to organize the desalination plants distribution based on brackish water availability, areas' needs and capacity.

- Monitoring program for the desalinated plants should be developed for evaluating the product and distributed water.

- To avoid the negative environmental impact, the disposal of brine should be considered and EIA must be conducted.

- Awareness campaign targeting the consumers to increase their awareness about the drinking water recommendations and healthy water quality.

- Palestine is in a great need for capacity building in the field of water desalination technology.

- Further researches on feasibility of desalination and effluent reuse will be needed in order to improve the efficiency and minimize the cost.

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