Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2020.25303

188 (2020) 450–463
June

Impacts of trade of reclaimed wastewater on water management in Palestine

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Received 21 June 2019; Accepted 21 December 2019

ABSTRACT

Water scarcity is one of the most difficult problems facing Palestine. The lack of available water resources and competition between different uses; domestic, agricultural and industrial is increasing year by year. Reuse of reclaimed wastewater has great potential to alleviate water scarcity problems and improve crop yield. The treated wastewater resource is an environmental, social and economic good that needs to be managed appropriately. Palestine, as in most of the neighboring countries in the region, acknowledges the importance of this resource in improving the water deficit by reusing the reclaimed wastewater in agricultural production, industrial sector and recharging groundwater aquifers. One alternative is to trade the reclaimed wastewater at some locations against water at other locations, or trade-offs this reclaimed wastewater. Data related to wastewater quantities, collection, treatment, transportation and reuse has been collected and analyzed as a baseline assessment. The pros and cons analysis method had been used in the analysis as to study the, among other, trade impacts of reclaimed wastewater. Social, environmental and other possible impacts have been also addressed. Depending on the interviews with the related people and decision-makers at the Ministries of Agriculture, Environment Quality Authority, Ministry of the National Economy and Palestinian Water Authority, they all welcomed of the concept of trade of reclaimed wastewater.

Keywords: Wastewater treatment; Reclaimed wastewater; Water resources; Options; Trade; Trade-off; Water quality; Water quantity; Pros and cons analysis

1. Introduction

Water scarcity is one of the most difficult problems facing Palestine. The lack of water resources and competition between different uses, domestic, agricultural and industrial, is increasing year by year. The pollution of water resources is also restricting the availability of water; the wastewater cesspits used by Palestinians are a source of groundwater pollution. The high water usage, as well as disposal of wastewater from Israeli settlements in the West Bank, is cited as contaminating the soil and further reducing the water resources available for the Palestinians [1].

In 2016, the total amount of water consumed in the West Bank and Gaza provides each person with an average of 84 L per capita per day (LCD) in Gaza (95% of Gaza water with an unaccepted quality), 82.3 LCD in the West Bank with an overall average of 83 LCD [2,3]. The 83 LCD is not particularly high value. It is one of the lowest rates in the Middle East.

As the water resources are not evenly distributed among the Palestinian cities and areas, the reuse of reclaimed wastewater may face obstacles due to water availability in addition to other social and economic factors. This means that reclaimed wastewater might be needed to be transported from the wastewater treatment plants to the consumption centers. One alternative is to trade the reclaimed wastewater at some locations against water at other locations, or trade-offs the reclaimed wastewater.

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Trade of reclaimed wastewater has been among the different subjects that have been addressed in different meetings and workshops as a commercial and/or political solution to the water scarcity problems in the region.

This paper addresses the impacts of trade of reclaimed wastewater on the management of water resources in Palestine. It tackles the value of reclaimed wastewater and its trade as an alternate water resource.

2. Method

The methodology applied in this research is analytical. Data related to wastewater quantities, collection, treatment, transportation and reuse has been collected and analyzed as baseline data.

After that the interviews with institutions and relevant ministries are done to study their opinions to improve the decision-making and inform them of all scenarios.

Then the pros and cons analysis method are used, it is a simple process for decision-making to compile a 'weighted' scored. Pro means 'for', and con means 'against'; advantages and disadvantages. Pros and cons and the 'weighted' decision-making method is one major method applied in the analysis to study the impacts of trade of reclaimed wastewater on the water resources. Social, environmental and other possible impacts have been also addressed. It is a tool or technique which decision-makers use to choose between the four research scenarios or alternatives of action and in deciding whether a proposed project should go ahead or not.

For several options can be assessed against differing significant criteria or a single set of important factors. In any case, factors/options can be weighted and scored appropriately. This will provide a reflection and indication as to the overall attractiveness and benefit of the option concerned. If we have scored each item, we will be able to arrive at a total score, being the difference between the pros and cons options totals. The bigger the difference between the total pros and the total cons then the more attractive the option is. The biggest positive difference between pros and cons is the most attractive option or scenario.

The pros of trade of reclaimed wastewater might include alternative water resources, environment protection, job creation, etc. The cons of trade of reclaimed wastewater would include the cost of treatment and transportation, social and health aspects and other factors. Identifying all the consequences of trade of reclaimed wastewater is difficult because it involves predicting the future and dealing with uncertain interactions and interpretations between human activities and the ecosystems in which they take place. The paper had been managed to integrate the above factors and has employed these to assess the impacts of the trade and trade-off of reclaimed wastewater.

3. Water resources in Palestine

3.1. Surface water resources

There are currently very few surface water resources in the West Bank. Most of the Wadis flow only for a few weeks a year, usually as flash-floods after thunderstorms. Rainwater is hard to use and capture as, in most Palestinian valleys, the complicated geological/ geographical features complicate the construction of large storage dams (few plains, karstic limestone substratum, political restrictions, etc).

The main surface water resource on the West Bank is the Jordan River, which is heavily used for irrigation and domestic water supply by the Israeli side, especially upstream, Since 1967 the Palestinians do not have access to this water source. It is a trans-boundary resource, shared between Jordan, Syria, Lebanon and Palestine. However, the following facts should be considered: Jordan River; It mainly consists of two parts: the upper part that flows from the river headwaters (Hasbani, Banias and Leddan) into Lake Tiberias, while the lower part is the continuation of flow from Lake Tiberias to the Dead Sea at an altitude of 425 m below sea level. This huge reduction in flow is mainly due to diversion of the water by the Israeli occupation of more than 500 million cubic meters through the National Water Carrier that extends south to the Negev, in addition to the construction of many dams upstream. Moreover, natural factors such as evapotranspiration had an adverse impact on Jordan River flows. The Jordan River is threatened by the discharge of large quantities of untreated wastewater from Israeli illegal settlements located along and south of Lake Tiberias [4].

West Bank Wadis: the long-term average annual flow of floodwater through Wadis in the West Bank is about 165 Mm^3/y. Generally, the West Bank Wadis are classified by the direction of flow into eastern Wadis (towards the Jordan Valley and the Dead Sea) and western Wadis (towards the Mediterranean). Currently, about 1 Mm^3/y is being harvested through several agricultural bonds in the Jordan Valley and the small scale dam (retention structure) in Al Auja Area [5].

3.2. Groundwater resources

Palestine is mostly reliant on groundwater where the majority of the Palestinian water supply comes from this source either by wells or springs. The total renewable groundwater resources have been estimated as 578–814 Mm^3/y in the West Bank aquifer basins. In the West Bank, groundwater resources are contained in deep (karstic) limestone and dolomite aquifers. Most large production Wells are 200–800 m deep and the water table lies between 100 and 450 m below the surface. These aquifers are commonly divided into three main aquifer-Basins (Western, Eastern and North-Eastern). The Western and North Eastern basins flow to the 1948 occupied Palestine (Israeli side) where it constitutes one of the main groundwater resources. Table 1 lists the estimates of groundwater utilization in 2015 [6].

3.3. Non-conventional resources

3.3.1. Reuse of treated wastewater

For West Bank, there are few activities or projects for reuse (small scale projects on the community level are implemented such as Anza, Attil, Kharas). However, some reuse projects are proposed for North-West Nablus, Jericho, Tayaseer and Auja areas in the short-term vision. An additional water resource will become available through the scheduled developments of wastewater treatment plants.

Table 1
Groundwater utilization in Palestine

	Utilization 2015 (MCM)				
	Western aquifer	Northeastern aquifer	Eastern aquifer	Costal	Total
Israeli occupation	≥411	≥103	≥150	≥400	1,064
Palestine	37.6	21.6	64.8	177.5	301.5
More than 97% of the Gaza coastal aquifer is not suitable for drinking purposes					

Source: PWA, 2016.

This resource is already under development in the Gaza Strip (with a scheduled production capacity of 10 Mm^3/y) in North Gaza [7].

3.4. Desalination of seawater

There is one seawater desalination plant located in the middle area of the Gaza Strip (Deir El Balah) with a capacity of 600 m^3/d (0.22 Mm^3/y). The plant is working using two beach wells and is planned to be expanded to about 2,600 m^3/d (0.95 Mm^3/y) by the year 2014. A large seawater desalination plant with a capacity of 50 Mm^3/y, as a first phase, is scheduled to be constructed by the year 2017 and is to be located in the central part of the Gaza Strip. The desalinated water will be mixed with abstracted groundwater and distributed to the consumers through the distribution facilities. By this additional water as well as other water and treated wastewater, it is expected that the coastal aquifer can recover to its original steady state.

The Gaza Strip borders the Mediterranean Sea, a nearly unlimited source of saltwater. This resource can be used for soft water production in Palestine, as it is in other Mediterranean countries (Israel, Algeria, Spain, Greece, etc.). Seawater desalination technologies are mature and there is a significant number of competing manufacturers of reliable equipment in the market (many of them with good track records of producing desalination plants of the same type as planned in Gaza).

Palestinian Water Authority (PWA) had identified a large desalination project for Gaza, with a 55 Mm^3/y capacity in 2017 (to be expanded to 129 Mm^3/y in the future). The plant site has been secured (along the coast) and preliminary negotiations are underway with development banks and donor organizations. Additional equipment could be installed on the same site or other similar sites in the Gaza Strip. Seawater resources are not available for the West Bank, except as part of a long-term strategy of regional water resources management: desalinated water could be conveyed from Gaza to the West Bank or through an equitable agreement with the Israeli occupation. This could be also tackled as part of the trade and/or trade-offs concept of available water resources in Palestine.

3.5. Desalination of brackish groundwater

Small pilot desalination projects for Brackish Water exist mainly in the Jordan Valley established by the private sector with a total capacity of less than 0.5 Mm^3/y. These are used mainly for agricultural purposes. A large facility is planned downstream from the Fashka Springs, near the Dead Sea (with a scheduled production capacity of at least 22 Mm^3/y by the year 2022). This project will increase water supply for the southern part of the West Bank and will finally be extended to produce 40 Mm^3/y in the future. Further developments in the reuse of treated and reclaimed wastewater should be undertaken in both Gaza and the West Bank. This potential resource could be relatively large, but its development raises important issues that are yet to be resolved. Among these issues is the acceptance to reuse reclaimed wastewater as an alternative to available freshwater especially in the areas that are relatively rich in freshwater. This is the case in Tulkarm and Jericho.

Trade of reclaimed wastewater is presented here as a possible solution to the problem of rejection of reuse due to the availability of freshwater. It suggests the trade of reclaimed wastewater against freshwater at other places. It also considerate transport of the available water to an area suffering a shortage in freshwater.

3.6. Water regulatory frameworks

The violation of the right of the Palestinian to equitable and fair utilization of the shared water resources is contrary to the spirit and principles of customary international law and has long been one of the major obstacles to cooperation and the achievement of peace in the Middle East.

The "Oslo Declaration of Principles" in September 1993 signed and the agreements between Israeli side and Palestine has stressed:

- Cooperation among both parties for the management of the water resources and development of the water infrastructure.
- Equitable utilization for joint resources.
- Environmental protection and prevention of environmental risks, hazards, and nuisances.
- Apply and ensure compliance with internationally recognized standards.
- Recognized the need to protect the environment and utilize natural resources on a sustainable basis.

3.7. Palestinian national water policy

The adoption of the elements of the National water policy in September 1995 represented the first step in addressing the important issues of water resources management and planning. The National water policy establishes the foundation for decisions regarding the structure and tasks of water

sector institutions as well as water sector legislation. It also underpins the necessity of the sustainable development of all water resources and establishes the principle that water resources are public property. Clearly, the development of the water resources of Palestine must be coordinated on a national level and carried out on the appropriate local level.

3.8. Water resources management strategy

The overall development objective of the water management strategy is to translate the messages from the National water policy into strategic imperatives. The strategy emphasizes the necessary aspects of water development as the establishment of a comprehensive framework for the sustainable management of Palestine's water resources, in addition to the development of an appropriate institutional set-up for reforming and strengthening the water sector in coordination with relevant stakeholders. This long-term and coordinated strategy for the water sector will be used as an overall basis for further planning relating to the activities and tasks associated with the water sector, with the main objective being the securing of environmentally sound and sustainable development of the water resources through efficient and equitable water management. The eight key elements of the recently developed water resources management strategy are [8]:

- Secure the Palestinian Water Rights.
- Strengthen national policies and regulations.
- Develop institutional capacity and human resources.
- Improve information services and assessment of water resources.
- Regulate and coordinate integrated water and wastewater investments and operations.
- Enforce water pollution control and protection of water resources.
- Develop public awareness and participation.
- Promote regional and international cooperation.

3.9. Water law No. 3 for 2002

The objective of the water law of 2002, as stated in Article 2, is to "develop and manage the water resources, increasing their capacity, improving their quality and preserving and protecting them from pollution and depletion". This objective is fulfilled through:

- Sustainable development of water resources based on environmentally sound and enabling bases;
- Provision and satisfaction of societal and individual needs for water optimally and equitably; and
- Protection of all water resources from pollution to secure water quality, an environment not harmful to human health or well-being, and sufficient water for production and self-renewal.

3.10. Water law for 2014

Stated the same objective of the water law of 2002. "All water resources are public-owned", "this law aims to develop and manage the water resources in Palestine, to increase their capacity, to improve their quality, to preserve and protect them from pollution and depletion, and to improve the level of water services through the implementation of integrated and sustainable water resources management principles". The law has enabled the establishment of water utilities and water users associations. Water sector regulatory council established the following provision of this law:

- Council named "The water sector regulatory council" shall be established by a decision of the cabinet of ministers and shall be regulated according to this law. The council enjoys a legal personality and is financially and administratively independent.
- Main headquarter of the council shall be in Jerusalem, and it is temporary headquarter in any other place in Palestine; The Council's Board.

The objective of the council is to monitor all matters related to the operation of water service providers including production, transportation, distribution, consumption and wastewater management, to ensure water and wastewater service quality and efficiency to consumers in Palestine at affordable prices. The council shall enjoy the same exemptions and privileges applicable to ministries and governmental departments. The law also determined in "Article Number 6" the purposes of using water and these purposes are: (a). Domestic and residential, (b). agriculture and irrigation, (c). industrial, (d). tourism, (e). trade and commerce and (f). conservation of water-dependent ecosystems and aquatic habitats.

4. Study area

The name West Bank is a translation of the Arabic term ad-Daffa al-Gharbiya, given to the territory west of the Jordan River, Fig. 1. The term was chosen to differentiate the West Bank of the River Jordan from the east bank of this river.

In June 1967, the West Bank and East Jerusalem were occupied by Israeli side. The West Bank is under Israeli military control. Since the 1993 Oslo Accords, the Palestinian National Authority officially controls a geographically non-contiguous territory comprising only 11% of the West Bank (known as Area A) which remains subject to Israeli military incursions. Area B (28%) is subject to both Israeli military and Palestinian Civil Control. Area C (61%) is under full Israeli control. Israel's occupation of the West Bank is not recognized by any state.

In 2013, State of Palestine was accepted by United Nation (UN) as an observing member. In the November 29, 2012, the date of the International Day of Solidarity with the Palestinian People. قدم الاقتراح ممثل فلسطين في الأمم المتحد The motion, the representative of Palestine to the United Nations. التصويت كان لمنح فلسطين صفة دولة غير عضو في الأمم المتحدة The vote was to give Palestine a non-member status at the United Nations. Basically, elevating the resolution of Palestine arranged a non-member entity to a member. فلسطين ومارست السابق حقها في الجزاء الدولية الخاصة مع رفض الخاصة الإسرائيلية القرار، إلا أن رئيس الوزراء مر ة بموجب الخاصة الأممية في 18 نوفمبر 2013، بالتصويت لانتخاب أحد قضاة محكمة بيو غوسلافيا السا التصويت لأول The broad population characteristics of Palestine are strongly influenced by political developments, which have played a significant role in the growth and

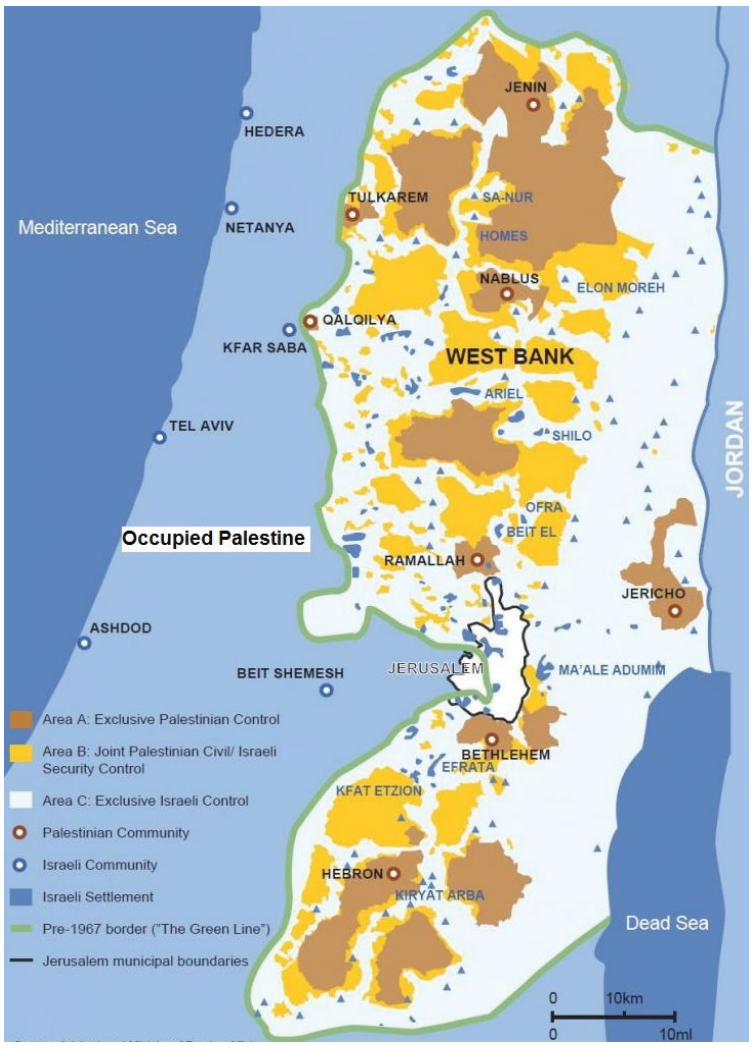

Fig. 1. Study area.

distribution of population in the Governorates. According to Palestinian Central Bureau of Statistics, a total population of 4.4 million live in the two geographical areas, 61.5% in the West Bank including Jerusalem and 38.5% in Gaza Strip [9].

4.1. Geography

West Bank with an area of approximately 5,800 km^2 is made up of a hilly region in the West and the Jordan Valley in the East and has generally rugged mountainous terrain. The total length of the land boundaries of the West Bank is 404 km^2. The terrain is mostly rugged dissected upland, some vegetation in the west, but somewhat barren in the east. The elevation span between the shoreline of the Dead Sea at –408 m to the highest point at Mount Nabi Yunis, at 1,030 m above sea level. The area of West Bank is landlocked; highlands are main recharge area for the groundwater coastal aquifers.

4.2. Climate

The climate in the West Bank can be characterized as hot and dry during summer and cool and wet in winter. The climate in the West Bank is mostly Mediterranean, slightly cooler at elevated areas compared with the shoreline, west to the area. In the east, the West Bank includes the Judean Desert and the shoreline of the Dead Sea, both with a dry and hot climate.

4.3. Palestinian Governorates

West Bank is divided into 11 governorates under the jurisdiction of the State of Palestine. Table 2 lists the Palestinian Governorates in the West Bank and the population and area for each.

4.4. Economy

The economy of Palestine is chronically depressed, with unemployment rates constantly over 20% since 2000 (19% in the West Bank in the first half of 2013). The main reason for economic depression is the Israeli occupation. According to a 2007 World Bank report, the Israeli occupation of the West Bank has destroyed the Palestinian economy, in violation

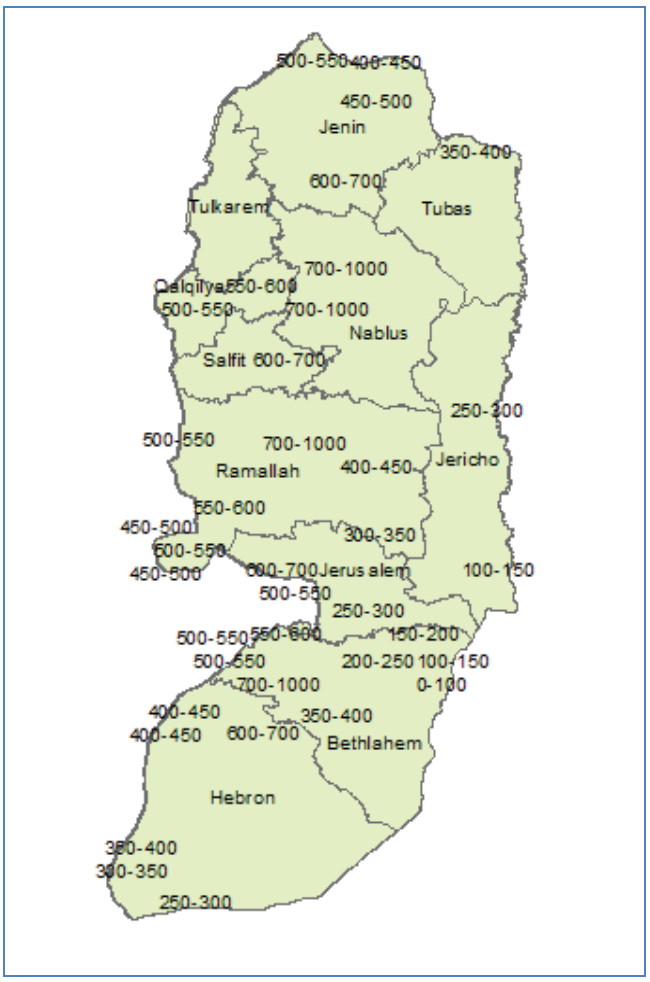

Fig. 2. West bank rainfalls.

of the 2005 Agreement on Movement and Access. All major roads (with a total length of 700 km) are basically off-limits to Palestinians, making it impossible to do normal business. Economic recovery would reduce Palestinian dependence on international aid by one billion dollars per year. A more comprehensive 2013 World Bank Report calculates that, if the interim agreement was respected and restrictions on the Palestinian are lifted, a few key industries alone would produce USD 2.2 billion per annum (about 23% of the 2011 Palestinian growth domestic product) and reduce by some USD 800 million (50%) of the deficit; the employment would increase by 35%.

4.5. Water consumption

According to the Palestinian Water Authority, the average Israeli domestic consumption of water is 350 L per person per day, which is more than four times that of the Palestinian use of 83 L/d. Some Palestinian villages live on even less water than the average Palestinian consumption, in some cases no more than 20 L per person per day. According to the World Bank, water extractions per capita for West Bank Palestinians are about one-quarter of those for Israelis, which have declined over the last decade. This has decreased the available per capita water consumption over the latest's years in West Bank. The lack of access to additional water resources has forced the actions forwards reusing of reclaimed wastewater.

Table 2
Palestinian governorates

Governorate	Population	Area (km^2)
Tulkarm	175,213	239
Tubas	65,771	372
Salfit	55,464	191
Ramallah and Al-Bireh	260,018	844
Qalqilya	120,753	164
Nablus	386,380	592
Jerusalem	462,521	344
Jericho	48,724	608
Jenin	556,212	583
Hebron	751,129	1,060
Bethlehem	257,515	644
Total	3,609,700	5,671

Source: PCBS, 2017

4.6. Water tariff

Prices paid for water itself are different from water tariffs, a water tariff is a price assigned to water supplied by a public utility through a piped network to its customers. The term is also often applied to wastewater tariffs. Water and wastewater tariffs are not charged for water itself, but to recover the costs of water treatment, water storage, transporting it to customers, collecting and treating wastewater, as well as billing and collection [10]. According to the recently developed water strategy water tariffs can be set by each water utility itself, according to (a) full cost recovery principle; (b) cost analysis tools developed by the Palestinian Water Authority; and (c) actual running costs accounted for by the water utility itself.

The water tariff and the basis for its calculation by each water utility will be objected or approved the tariff by the water regulatory council. The average tariff system in the West Bank governorate can be summarized in Table 3, the maximum tariff includes Water Tankers prices.

4.7. Rainfall

The annual rainfall in the West Bank varies from about 650 mm in the western part to less than 100 mm in the east; the long-term annual average is about 454 mm, Fig. 2 shows the annual rainfalls in West Bank. During the past 8 y, the average accumulated annual rainfall increased in the northern and north-western parts of the West Bank.

4.8. Agriculture in West Bank

Agriculture is an important cultural tradition vital to the economy of the West Bank. Farming has been a part

Table 3
Water tariffs in the west bank governorate

Governorate	Average tariff (NIS/m^3)	Maximum tariff (NIS/m^3)
Bethlehem	4.6	15
Hebron	5.4	20
Jenin	4.3	19
Jericho	2.5	5
Jerusalem	4.1	–
Nablus	4.5	15
Qalqilya	4.1	18
Ramallah	4.1	9.7
Tulkarm	3.1	20

Source: Aslan, 2013

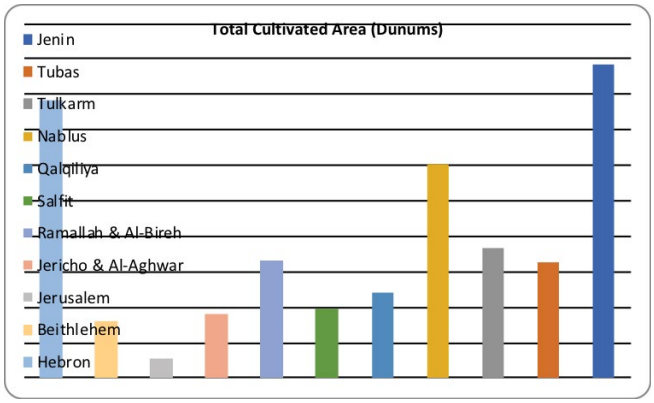

Fig. 3. Total cultivated areas in West Bank Governorates.

of Palestinian life for thousands of years, not only providing communities with food and jobs, it is a source of pride and a means of self-sufficiency. From drier and drier seasons to ever-changing political obstacles, both physical and bureaucratic, farming in the West Bank faced major challenges to a way of life and livelihoods.

Palestine is famous for growing olives, almond, citrus and grapes as fruit trees, distributed as follows: olives mainly grow in Nablus, Jenin, Ramallah, and Tulkarm. Almonds mainly grow in Tulkarm, and Jenin, while citrus grows mainly in Qalqilya, Nablus, Tulkarm, and Jericho, finally grapes are mainly produced in Hebron and Bethlehem [3].

West Bank interest in producing different kinds of vegetables mainly tomato, squash, cucumber, which depend on rain feed or irrigation, in most governorates the greenhouse, is used to increase their productions [3]. Wheat considered as the main type of field crop which mainly grows in Jenin, Hebron, and Tubas, irrigated by irrigation system or depended on rain-fed. The next Fig. 3 shows the total cultivated area in Dunums in the study area governorates; the biggest cultivated areas in Jenin, Hebron, and Nablus then Tulkarm, Ramallah and Tubas.

Jenin, Hebron and Nablus are the largest governorates that have the highest cultivated areas. Nevertheless, these three governorates are suffering from water scarcity. Therefore, providing additional water to these areas will enhance the agricultural activities because that it is possible to think of using the reclaimed wastewater from these cities to their needs or from other cities, and that is what the thesis will talk about it later.

4.9. Data collection

Data collection consists of the data gathering mainly from the PWA, the Palestinian Central Bureau of Statistics (PCBS), and other Palestinian Ministers and Municipalities.

4.10. Water available quantities

The quantities of water made available to the consumers vary from region to region. These quantities reflect the local water resource available, as well as the investments made over recent years to improve the water service reliability and water quantities in some cities. The northern and southern parts of the West Bank are particularly affected by lack of water. This is mainly due to the Israeli restrictions that prevent Palestinians from utilizing their water resources, drilling new wells, rehabilitating existing wells and transporting water from one region to another. Palestine has serious water problems in that it is denied its access to water rights, whilst the Israeli side abstracts water from the West Bank for ever-expanding settlements and sells what little remains back again to Palestinians. Palestinian attempts to maximize and redistribute available supplies are hampered by total control of the Israeli side and severe restrictions in the building or rehabilitation of water infrastructure.

Due to the water scarcity, many communities in the West Bank hire water tankers for their supply. This is reflected in the average tariff per governorate, which is relatively high in Hebron, Jenin and Tubas, that is, in those governorates where many communities are obliged to use water tankers, with tariff rising to 20 ILS/m^3, and in some communities even more.

The majority of those West Bank inhabitants with no piped water supply are located within the following four governorates:

- Hebron Governorate, 31 communities (27,551 inhabitants) are still not served by water supply networks and pay very high tariffs for tanker water; the water piped to customers amounts only to 55 LCD;
- Jenin Governorate, 9 communities (19,013 inhabitants) are still without access to water supply networks and pay very high tariffs for tanker water; the water piped to customers amounts only to 41 LCD;
- Nablus Governorate, 16 communities (47,235 inhabitants) are still not served by water supply networks and pay very high tariffs for tanker water; the average water piped to customers at the governorate level amounts to 84 LCD, as Nablus city itself is well serviced.
- Tubas Governorate, 8 communities (13,653 inhabitants) are still not served by water supply networks and represent 24.1% of the governorate population.

Fig. 4, plots the needed quantities for each governorate using a bar chart. It is clear that the governorates (Nablus,

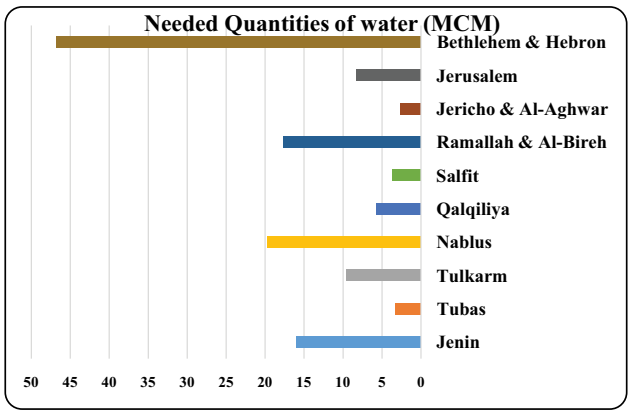

Fig. 4. Needed quantities of water for each governorate.

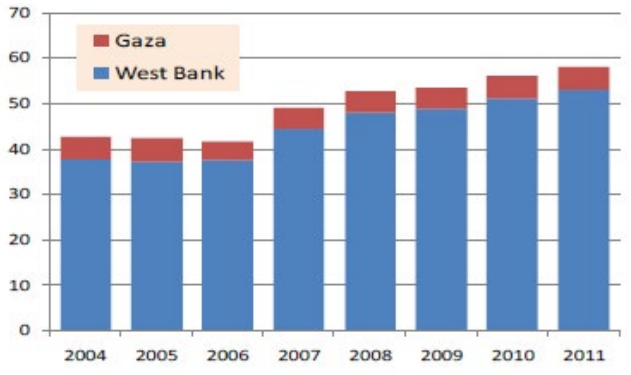

Fig. 5. Annual quantity of water purchased from Mekorot for domestic use (Mm^3/y).

Hebron, Jenin, and Ramallah) have the highest needed quantities of water, this means we should concentrate on this research on these cities.

4.11. Bulk supply from Mekorot

Over 34% of the West Bank's water supply comes from water imported from Mekorot systems (Tel Aviv, Israel) [11]. To a certain extent, these imports offset the constraints imposed by the Israeli side regarding the construction of new wells and import levels have been increasing over the last few years. Fig. 5, plots the annual quantity of water purchased from Mekorot for domestic use (in Mm^3/y) [12].

4.12. Wastewater quantities

As to the water supply report, the wastewater quantities generated yearly in the West Bank are estimated at approximately 62 MCM (Million Cubic Meter) annually at a daily rate of about 170 Ml/d including municipal and industrial wastewater. Also 35 MCM annually; 96 Ml/d of untreated wastewater are discharged by Israeli settlements and industrial zones into the West Bank environment. Less than 5% of the wastewater is generated from industrial activities like in Nablus, Ramallah and Hebron. Fig. 6, plots the estimated generated wastewater in 2018 from the different governorates using a bar chart. It is obvious that three large cities or governorate (Nablus, Hebron and Ramallah) more than 10 MCM each [13–16].

The collected quantities from these wastewater collection systems are either treated in Palestinian central treatment plants like Al-Bireh or small collective treatment plants like Zeita and Attil or are dumped into surface water streams (Wadis) and then either treated in Israeli treatment plants like Jenin, Tulkarm, West Nablus, Beit Jala, and Hebron or disposed into Wadis. Around 15 MCM annually of wastewater is collected from several areas in the year 2017 is dumped in Wadis, and then treated in wastewater treatment plants inside the green line. At the expense of the Palestinian people, and treatment costs are directly deducted every month by the Israeli side from the Palestinian clearance account without any positive valuation of the treated waters. This water is reused by the Israelis [17–20].

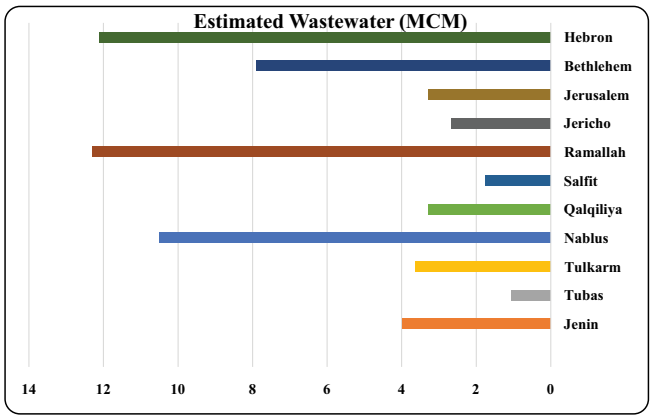

Fig. 6. Estimated wastewater quantities.

More than 6 MCM of untreated wastewater estimated to be generated from several communities in the year 2017 disposed into several streams that flow to the east and northeast of the West Bank. The other generated wastewater is stored in cesspits in the rural areas, where the estimated wastewater dumped into cesspits is around 41 MCM (112 Ml/d). Around 2 MCM (54 Ml/d) is collected in Al-Bireh and surrounding refugee camps and treated in Al-Bireh WWTP and then dumped into Wadi Al-Qilt without reuse. In addition to a few quantities treated in small scale collective systems and reused locally, but this amount considered as negligible compared to the total generated wastewater [21].

4.13. Wastewater treatment in West Bank

There are only a few central wastewater treatment plants constructed that are operating. These are in Nablus, Tulkarm, Jenin, Al-Beireh, Ramallah. These primary treatment lagoons have formed the only significant wastewater treatment in recent years. Nablus West wastewater treatment plant. The ponds that were built in the mid-1970s had not been improved or upgraded until the advent of the Palestinian National Authority and the creation of the PWA in 1996 [22]. Despite the increase in wastewater quantities flowing into those ponds and plants they were all operating beyond their maximum capacities. The result of this has led to partially

treated wastewater being discharged in areas surrounding these plants. The result of this has been multiple environmental and sanitary problems [23].

Throughout this period, wastewater from Palestinian cities has been and is still discharged into West Bank Wadis and natural waterways. In some cases, water even flows inside of the green line, where it is collected and treated in treatment plants built originally to treat Israeli Wastewater or plants build specifically to treat the Palestinian wastewater crossing the border [24].

The PNA has built one treatment plant at Al Bireh in 2000 in the West Bank. This plant has a treatment capacity of up to 2 MCM 5.5 Ml/d. West Nablus is also under operation, and is expected to start construction at Ramallah (Ain Jeriout), Hebron, Jericho, Tubas and Nablus East. Also, there will be some de-centralized plants in rural areas that are now under construction in Anza, Beit Dajan, Sarra, Hajja, Beit Hasan, Taybeh-Rammoun. Construction is expected to start in Misilya, Al-Aroub, and the Bethlehem Industrial Zone [25].

4.14. Central wastewater treatment plants

There are only a few central wastewater treatment plants (WWTPs) that are operating, located in Nablus Al-Bireh, Ramallah, and Jenin cities in addition to the Tulkarm pre-treatment wastewater plant. The WWTP in Jenin rehabilitated and started operation in October 2012 [26]. A new central WWTP is now under operation to serve the western area of Nablus city and the nearby five villages with the support of the German Government. This is being funded through the German Development Bank (KfW), Fig. 7 shows the location of the wastewater treatment plants within the study area [27].

Several donors committed to helping the Palestinian improve the wastewater sector in terms of collection, treatment, reuse and capacity building. Table 4 shows the status of the ongoing projects in West Bank (name, service area, donor, budget, type of the project) [28].

It is clear from previous tables that there are big draws in more than one governorate in Palestine towards the establishment of a wastewater treatment plants, especially those projects funded from donors, which require the study of more than one way to take advantage of this reclaimed wastewater [29].

4.15. Trade and trade-off of reclaimed wastewater in Palestine

Trade is the economic fundamentals that are just as important as the rest of the other economic activities being help in securing freedom for basic goods for the domestic market and create competition in the market. Palestinian trade is different from the rest of the other countries at a time that we are in desperate need of free trade, baptizing the Israeli side to put economic policy planned to impose restrictions and put obstacles to paralyze the Palestinian economy and the Israeli economy attachable [30–32].

The concept of deriving beneficial uses from treated municipal and industrial wastewater coupled with increasing pressures on water resources has prompted the emergency of wastewater reclamation, recycling, and reuse as integral components of water resource management. The inherent benefits associated with reclaiming treated wastewater for supplemental applications before discharge or disposal include preservation of higher quality water resources, environmental protection, and economic advantages. A major catalyst for the evolution of wastewater reclamation has been the need to provide alternative water sources to satisfy water requirements for irrigation, industry, urban non-potable and potable water applications due to unprecedented growth and development in many regions of the word. Water shortages, particularly during periods of drought, have necessitated stricter control measures on rates of water consumption and the development of alternative water resources. This thesis will address in several ways and scenarios for a trade of reclaimed wastewater as follows;

- Trade or trade-off of reclaimed wastewater between Palestine and the Israeli side.
- Trade or trade-off of reclaimed wastewater among Palestinian Governorates.
- Trade-off of reclaimed wastewater in agriculture.
- Trade of reclaimed wastewater in the industry.

Fig. 8 shows thesis scenarios for the trade of reclaimed wastewater. To study the possibility of the application of these options have been used method of interviews to support this research; several interviews with the related ministries had been done, and each scenario addressed in details with a determination of the benefits and constraints of each option and the opinion of the related ministries for each option and the possibility of the application of this option in Palestine [33–35].

4.16. Data analysis and outputs

The scientific method of the research is (pros and cons analysis) for each of the scenarios and then to determine if the value of the scenario is positive or not, and also to determine the best scenario have the maximum weight, several economic, social, political and environmental factors had been addressed [36].

Pros and cons analysis is a systematic process for making difficult decisions that involve a lot of factors by which the advantages and disadvantages of the scenario well measure and compare for the governmental decision-makers. The analysis provides a reliable basis in the comparison between scenarios. This process is built based on the comparison between the expected total advantages (pros) of each option against the total expected disadvantages (cons), to see whether the advantages outweigh the disadvantages. So it will be as much as possible to try to limit the advantages of each scenario from the proposed scenarios vs. the disadvantages of this scenario, in addition to the possibility of a more than one scenario in the trade or trade-off of reclaimed wastewater even follow all the previous options [37–40].

Before making any decision related to trade or trade-off of reclaimed wastewater we should take into account the aspects related to both advantages and disadvantages for the proposed scenarios. The research determined the benefits (advantages) and obstacles (disadvantages) for every

Table 4
Wastewater projects under preparation, implementation and completed

No.	Wastewater project	Donor	Design capacity (m^3/d)	Estimated cost	Status	Population	Components
1	Jenin, Misilya village	AFD	400	2.8 M€	Under construction	4,000	Collection system, WWTP, reuse system
2	Tubas, Tayaseer	EU	3,000	22 M€	Under detailed design	25,000	Collection system, WWTP, reuse system, capacity building
3	Ramallah, Betunia-Ein Jariot	KFW	10,000	27 M€	Design phase	59,000	Collection system, WWTP, reuse system
4	Hebron, WWTP	WB and AFD	15,000	38 M$	Feasibility study and EIA	300,000	Collection system, WWTP, reuse system, capacity building
5	Rehabilitation of Jenin TP	KFW	9,000	1.5 M€	Completed	55,000	Rehabilitation of existing WWTP
6	Tulkarm sewerage project	KFW	–	19 M€	Under construction	75,000	Collection system, trunk line, pre-treatment
7	Anza, Beit Dajan, Hajja, Sir, At-Taybah, Rammun	EU	200–400	9.0 M€	Under construction	20,000	Collection system, WWTP, reuse system, capacity building
8	Al-Yamun, Qabatiya, Ya'abad, Azzun, Tarqumiya, Dura	USAID	18,000–30,000	Each (20–25 M $)	Design completed	150,000	Collection system, WWTP, reuse system, capacity building
9	Beit Hasan sewerage project	Spain	100	0.31 M $	Design phase	8,000	Construction of WWTP and collection system
10	Al'Aroub WWTP project	Spain	1,200	1.5 M€		–	Construction of WWTP
11	Habla, Baqa, Barta'a	Japan	–	6.2 M $	Completed	22,000	Collection system
12	Northeast Jerusalem wastewater project	Finland	–		Sanitation and baseline study	30,000	Collection system, WWTP, reuse system, capacity building
13	Rawabi regional sewerage project	USTDA	–	0.5 M $	Feasibility study	–	Collection system, WWTP, reuse system, capacity building
14	West Bethlehem villages water supply and sanitation project	WB	–	3.65 M $	TOR for the feasibility study	25,000	Collection system, WWTP, reuse system, capacity building
15	Upgrading existing small scale WWTP in rural area	Austria	–	0.22 M€	Implementation phase	20,000	Rehabilitation of existing WWTP
16	Artas sewage project	BTC	–	0.6 M€	Completed	5,000	Collection system and poster station
17	Hebron industrial area wastewater project	USAID	–	1.5 M $	Implementation phase	–	Cleaning industrial zone from slurry generated by stone cutting factories
18	Bethlehem industrial zone WWTP	AFD	–	Phase1: 0.5 M€ Phase2: 3.5 M€	Constructed, waiting for sewage	Phase 1: 100 Phase 2: 500	Collection system and WWTP
19	Al-Rihan neighborhood wastewater project	Private	–	–	Construction phase	500	Collection system and WWTP
20	Al-Tireh neighborhood wastewater project	Private	–	3.8 M $	Construction phase	2,000	Collection system and WWTP
21	North Gaza Beit Lahiah	Private	–	1.5 M $	Construction phase	500	Collection system and WWTP

scenario and then tabulated these factors for comparison between them. These analysis steps are:

- Making a table that has all the factors and indicators as columns and all the scenarios as a row.
- Giving a weight for every factor that affects in the scenario, the weight varies from –4 to +4
- Counting the number of pros and cons. By assigning each pro and con a weight, it can get a better sense of where the balance really lies.
- Highest number means it is an extremely important factor in the decision.
- Completing a table for all the options that had been considered.
- Total number of points in the weights column was contributed and then determined and compared the results.

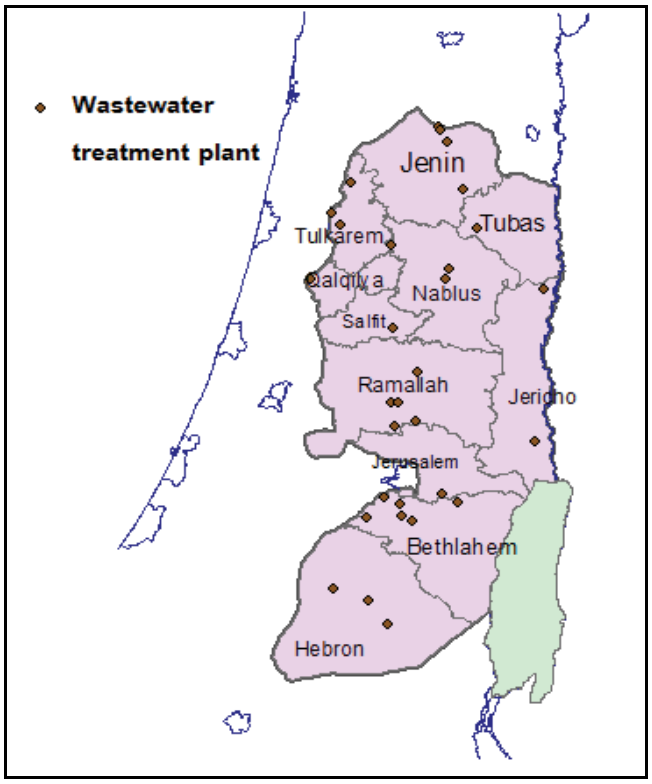

Fig. 7. Wastewater treatment plant located in the West Bank.

As we can notice from the above Table 5 that the best choice according to the pros and cons analysis is the trade of reclaimed wastewater at the same governorate for industrial uses, because of that choice decrees the costs of transportation (it is the same as a tradeoff for agricultural uses at the same governorate), but without holding the disadvantages of poisoned the land and plants and the bad effects on reputation at the neighbor countries; with that choice Palestinian are more free to make their own decisions in comparison with the other choices that related to the Israeli side.

The second best choice is trading off with Israeli side because this choice can offer fresh water for Palestinians without holding of any of the bad effects for the environment or Palestinian society because the reclaimed wastewater will not be used for any purpose at the Palestinian areas, in addition, to support the peace idea with the Israeli side.

The third best choice is trade with Israeli side because within this choice is good for the economical income and it can offer jobs opportunities, and also during to this choice Palestinians will have money and they will have nothing to lose at this stage they already have reclaimed wastewater without any benefits; also this choice can support the peace with Israeli side (two countries solution).

Palestinian can decide the best choice according to the strategic plan; because of the trade-off, even at the same governorate or between governorates for industrial purposes, can be better for the long term; which can be better according to the sustainability vision and the freedom of the State of

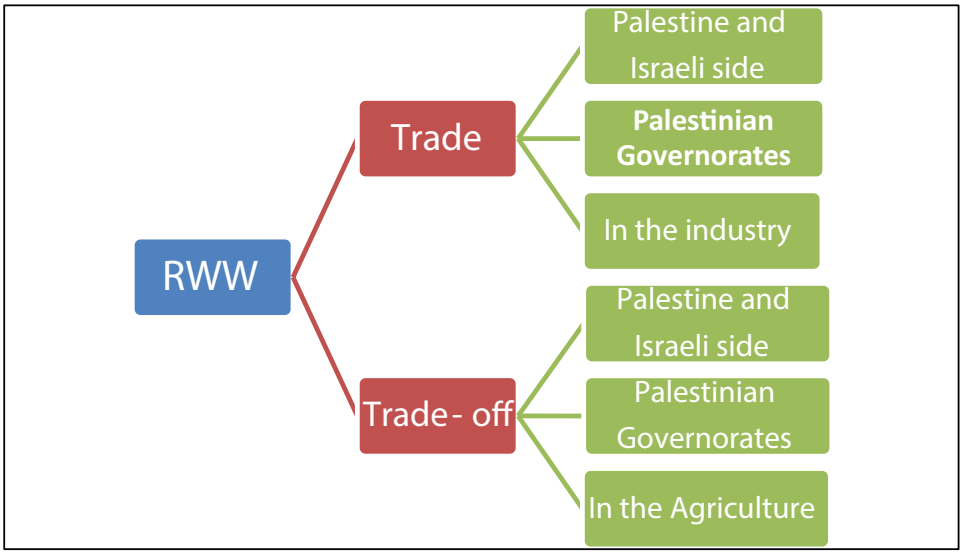

Fig. 8. Trade of reclaimed wastewater scenarios.

Table 5
Pros and cons analysis for all scenarios

Scenarios of trade and trade-off of RWW	Indicator	Economical indicators							Political indicators				Environmental indicators		
	Scenario	Translation costs	WW network costs	Storage costs	Tankers costs	Reflect on the relation with neighbor countries	Job opportunities	Economical income	Israeli control	Rejection agreements	Decision freedom	Controlling the national sources	Clean agriculture using fresh water	Land and plants poisoned	Better environment
	Trade with Israel	-3	-2	-1	-3	*	+2	+2	+1	*	+2	+2	+1	+2	+1
	Trade between governorates	-3	-2	-1	-2	-2	+2	+2	+3	*	+2	+3	+2	+2	+2
	Trade-off with Israel	-4	-2	-1	-3	*	+3	+3	+1	*	+1	+2	+2	+2	+2
	Trade-off between governorates	-4	-2	-1	-2	-2	+3	+3	*	*	+2	+2	+2	-1	+1
	Trade-off for Agricultural use at the same governorate	-1	-2	-1	-1	-3	+1	+2	*	*	+3	+2	-2	-2	+1
	Trade as industrial water	-1	-2	-1	-1	*	+1	+1	*	*	+2	+2	+3	+2	+2

Scenarios of trade and trade-off of RWW	Indicator	Development indicators				Social indicators					Total
	Scenario	Resources sustainable	Decrease the fresh water losing	Save the new generations rights	Improve the income average	Social rejection depending psychological reasons	Social rejection depending on religious reasons	Illegal within local laws	Effectiveness for the neighbor countries	Effecting the Palestinian reputation	Total
	Trade with Israel	+3	*	+3	+1	*	*	*	*	*	+11
	Trade between governorates	+3	+3	+3	+1	-2	-2	*	-2	-2	+10
	Trade off with Israel	+3	+2	+3	+2	*	*	*	*	*	+16
	Trade off between governorates	+3	+2	+3	+2	-1	-1	*	-2	-2	+5
	Trade off for Agricultural use at the same governorate	+3	+3	+3	+2	-2	-2	-1	-2	-2	+1
	Trade as industrial water	+3	+3	+3	+2	*	*	*	*	*	+19

Palestine, on the other side trade with Israelis can be better for the short term plans; because this choice can offer an economical income for Palestinians which can help them to pass the financial difficulties that they are facing at this time, but it's not a good choice for the long term because of water as a limited natural source more important for the long term than the financial sources.

5. Conclusions

Reclaimed wastewater is an important unused natural source, it is important to maximize the benefits that we could get by using such an important source should be considered, especially with the growth of the treatment projects that produced a large amount of reclaimed wastewater, according to the research there are more than one scenarios can be used in Palestine, many factors affect in the option that will use by decision-makers, these factors like quantities of water, distance from the Israeli side, nature of agriculture and industrial types in every governorate. For sustainable development, the best scenarios can be even trade-off between governorates or trade between governorates or trade-off at the same governorate whatever the purpose of use, but for the short term trade-off or trade with Israeli sides can be a good scenario so that it can offer financial support which can help Palestinians to face budget difficulties. It is important to note that the maximum percentage of freshwater uses in Palestine is for the personal and agricultural uses, reclaimed wastewater can be used for all the other purposes such as; the industrial sector and the most

important industrial sector that reclaimed wastewater can be used in is the constructions sector.

The public awareness about the reuse of reclaimed wastewater in agriculture is very weak. Most of Public respondents do not understand the physical meaning of reuse. They think that religion and social traditions are prejudiced against wastewater treatment and reuse.

Depending on the interviews with the related people and decision-makers at the Ministries of Agriculture, Environment, Economic and Water Authority, they all welcomed the suggestion of reclaimed wastewater as an alternative solution to the water scarcity in Palestine. But it can be used without ignoring society and religion factors. Also, the price of reclaimed wastewater is an important factor to make these scenarios applicable.

Recommendations

As a result of the study, the official support is important to achieve the best results and to maximize the benefits that can be achieved, and it's important to organize an awareness campaign that can improve the society acceptability of reclaimed water using in the different sectors. Reclaimed wastewater is an important resource as an alternative choice instead of freshwater, but it is important to prepare economical, technical and social studies that can help the decision-makers to make the appropriate decisions, it can be used in irrigation of the green areas at the industrial parks and a successful stories of using reclaimed wastewater can be a good method to help society to accept using of reclaimed water.

Palestine Estate should have national unified strategy in the sector of water resources management especially reclaimed wastewater which is considered an important water resource should be used, but the applying of the research idea should not be a conflict with the Palestinian Water Rights, Also should work hardly to get more donors to support this project because of its importance for both of environment and economic with qualified and specialized staff in reclaimed wastewater issues is an important factor of succeeding this project. The government should be involved in the private sector within this project and must be addressed in terms of legality.

Before applying this project the determination of the reclaimed wastewater owner is very important; if it is the Ministry of Local Governorate within the Municipalities or PWA or any other parts; because these water ownership issues are problems can appear or face in the next future.

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