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Recycling of treated water in Palestine: Urgency, obstacles and experience to date

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Abstract

To provide piped water to rural areas of Palestine, low technology treatment plants and sewers should be installed at minimum cost and for ease of operation. Treated waters can also be used for irrigation. There should be training for selection of crops, running wastewater plants, recycling and public education for the idea of reuse.

Keywords: Recycling; Water treatment; Palestine

1. Introduction

Palestine consists of the West Bank and the Gaza Strip. The proclaimed State of Palestine has a land area of 6657 km^2 [1].

There are no exact statistics regarding the area of Palestine, the population, and specifically regarding water consumption, demand, and the total water available. No population census has ever been taken by Palestinians in the state; therefore, the population data is often based on official Israeli statistics and non-official Palestinian estimates. (Al Khateeb reports that the Palestinian population in the West Bank and Gaza ranges between the low Israeli figures of 1,800,000 and a higher estimated Palestinian figure of 2,149,000 for the year 1992 [1].) The total cultivated area is 2,314,000 dunams of which 230,000 dunams are under irrigation (for more details see Table 1).

Ground water is the main water source in the country. It is recharged by rainfall. Rainfall varies from 50 mm in the southeast to 800 mm in the north. The average rainfall is 550 mm [2].

Not all the rain water is available to the Palestinians due to Israeli military orders. Water is

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Table 1
Basic land and water indicators for Israel and Palestine and other Arab territories (1 dunam=1000 m^2)

	West Bank	Gaza	Israel
Total area (dunams)	5,573,000	360,000	20,000,000
Population (1988)	900,000	600,000	4,300,000
Area of land cultivated (dunams)	2,100,000	214,000	4,250,000
Area of land irrigated (dunams)	100,000	120,000	1,850,000
Percentage of total land cultivated	38	59	21
Percentage of total land irrigated	5	56	44
Annual water consumption for irrigation (million m^3)	95	80	1320
Annual water consumption for households (million m^3)	27	21	325
Annual water consumption for industry (million m^3)	3	2	125
Total annual water consumption (million m^3)	125	103	1770
Total per capita water consumption (m^3)	139	172	411
Per capita water consumption per household (m^3)	10	35	75
Per capita water consumption for industry (m^3)	3.3	3.3	29
Per capita water consumption for irrigation (m^3)	106	133	307

Source: Israeli land and water policies and practices in Palestinian and Arab territories; unpublished study in Arabic (Economic and Social Commission for Western Asia, Baghdad, 1990, p. 8).

abstracted from the ground water through 340 wells in the West Bank and 1781 wells in Gaza.

Running piped water is not available to all Palestinian villages, especially in the north. Fifty-six percent of all the West Bank villages lack running water, i.e., 196 villages from total of 351 villages [3]. Sewage collection serves only the major cities while there are only a few wastewater treatment plants in the country.

Treating wastewater and recycling for irrigation implies a positive impact on Palestinians, yet there is no mention of reuse projects in the country.

2. Water sources in Palestine

2.1. West Bank

Two main water sources are available for Palestinians in Palestine for agricultural, domestic and industrial use. They are rainfall and ground water sources. Palestinians consume water mainly through ground water wells and springs (where rainfall is considered the main recharge). The total annual water spring discharge varies according to the rainfall. In the average 60 mcm is the annual water discharge from the West Bank springs [2] while the total estimated annual water discharge from ground water wells is 60 mcm [4].

Another 2.5 mcm of water is collected directly from rainfall in cisterns in Palestinian houses [4]. So the total annual water consumption by Palestinians in the West Bank is 125 mcm. Of these 125 mcm, 16 mcm [2] are purchased from Jewish wells which were drilled inside the West Bank. Table 2 shows summary of the water consumption and usage in the occupied territories. This table shows that only 44 mcm are allowed for Palestinians in the West Bank to abstract water through the 340 Palestinian wells in 1990.

2.2. Gaza Strip

The water situation in the Gaza Strip is very critical. The Gaza Strip lies on top of two water strata. The upper is fresh water; the lower carries saline water. The annual consumption of water at present is in the vicinity of 100 mcm; the aquifer

Table 2A
Summary of water use in the West Bank (in mcm) in 1988 [2]

Source	Domestic	Agriculture
Local wells (Palestinians)	15	29
Israeli wells	5	11
Cisterns	5	—
Springs	10	50
Total	35	90

Table 2B
Domestic water consumption in the West Bank according to cities, m^3/y for 1990 [3]

City	Water consumption	Percentage
Jerusalem	4,564,199	17.73
Nablus	5,938,544	23.07
Hebron	4,350,262	16.9
Ramallah	3,273,988	12.72
Tulkarem	3,243,114	12.6
Jenin	1,771,316	6.88
Bethlehem	2,163,216	8.4
Jericho	441,183	1.71
Total	25,745,822	100

gets replenishment of some 60% leaving a deficit of 40 mcm of water [5].

In his report, Abu Safieh [6] states that the average amount of rainfall was calculated at 394 mm annually for the period from 1967 to 1990. The amount of rainfall is estimated at (399 mm × 365 km^2 area of Gaza×10=144 mcm), of which about 35 mcm reached the ground water aquifer, and this amount usually constitutes the main recharge source. In addition to that another 35 mcm feeds ground water aquifers either from the east or from water percolated down to the aquifers from irrigation and cesspools. Shuval [7] estimates the safe guard of the Gaza aquifer is about 65 mcm.

2.2.1. Domestic water use

The amount of water pumped from the fifty drinking water wells was calculated at 24.2 mcm for the year 1989 and the figure increased to 29.2 mcm in the year 1990. The annual figure for 1991 increased to 40 mcm [6]. The water consumption is stated to reach 59 mcm in the year 2010 [5]. Table 3 shows the domestic water consumption.

2.2.2. Agricultural water consumption

Water consumption for agricultural purposes was calculated at 52.7 for the year 1989, pumped from 1781 wells [6]. For the year 1990 the consumption was 65.7 mcm. This is expected to reach 150 mcm for the year 2010. These figures as well as domestic consumption do not include the water consumption by Israeli settlers.

It is clear that there is a deficit of water which is estimated to be at a minimum of 36 mcm of water annually according to Shuval [7].

2.3. The irrigated area in Palestine

In Palestine, which is a semi-arid country, we are confronted with demographic growth and agricultural development as well as livestock and industrial development. Thus an essential growing water requirement makes the rational management of water resources supremely important in order for development to be lasting and for the environment to be served. Agriculture is the largest water consumer. On a global basis at least 60% of all water abstracted at present is used for agricultural production. In Palestine 70% of all water consumed is for agriculture.

In Palestine, agriculture is considered to be one of the main sources of income. Agricultural production contributed 47.61% to the total income in 1970 in Gaza [8], but it was reduced to 26.9 in 1988. In addition, *at least 40% of all Palestine depends on agriculture.*

Total agricultural production in 1989 was $503,900,000. In 1989 the total number of employees in agriculture was 37,000 in the West Bank and 18,460 in Gaza — a total of 55,524. Agriculture accounts for employing more than 21% of the labor force.

Table 3A
Estimates of the total water and per capita overall water consumption in Palestine and Israel, mid-1980s [9]

	West Bank		Gaza		Israel
	Palestine	Settlers	Palestine	Settlers	
Total annual water consumption, mcm:	125	45	103	6	1770
Irrigation	95	—	80	—	1320
Households	27	—	21	—	325
Industry	3	—	2	—	125
Per capita annual water consumption, m^3:	139	2143	172	2326	411
Irrigation	106	—	133	—	307
Households	30	85	35	85	75
Industry	3	—	3	—	29

Table 3B
Water consumption according to its use in 1990 in mcm [4]

	West Bank (A)	Gaza (B)	Total (A+B)	Israel	Jordan
Total consumption	118	97	215	1750	879
Agricultural consumption	84	68	152	1162	657
Domestic	29	27	56	482	179
Industry	5	2	7	106	43
Population/1000	936	730	1666	4660	3453
Water consumption, m^3/y	326	133	129	376	255
Domestic consumption per person/y, m^3 mcm	31	37	34	103	52

2.3.1. Irrigation

The potential for irrigation to raise both agricultural productivity and the living standards of the rural poor has long been recognized. Irrigated agriculture occupies approximately 17% of the world's total arable land, but the production from this land comprises about 34% of the world total. This potential is even more pronounced in arid areas such as the Near East where only 30% of the cultivated area is irrigated, but it produces about 75% of total agricultural production [10].

In Palestine, irrigation is considered to be the spinal chord of plant production for the following reasons:

1. Palestine is considered a semi-arid region where some of the crops cannot be grown without irrigation (e.g., citrus).

2. In the Jordan Valley, which constitutes the main agricultural are for the country, irrigation is a must.

3. With irrigation the same plot of land can be planted three times per year while it cannot be planted more than two times with dry farming.

4. Different varieties and crops can be planted in any region due to the availability of water, i.e., more flexibility of planting several crops at different regions in different times of the year.

5. Job creation, since the labor requirement per irrigated dunam is more than double that of the job required per dry farming per one season.

6. Agricultural production is much higher for irrigated farming than for dry farming per dunam per season. As an example, the average tomato production per dunam is as follows: (a) dry farming — 3 tons per dunam per season; (b) irrigated (open land) — 8 tons per dunam per season; (c) irrigated (green houses) — 16 tons per dunam per season. More details will be presented below.

7. Net income per dunam of dry farming does not exceed $150 while from irrigated area the net income can exceed $1500 per dunam.

Due to the shortage of water, irrigated areas did not constitute more than 8% of the cultivated area in Palestine, while the total water consumed due to agriculture was 65 mcm in Gaza and 84 mcm in the West Bank in 1990 [8], for a total of 150 mcm.

2.3.2. *Future water consumption*

The current domestic water consumption for Palestinians in the West Bank including East Jerusalem and the Gaza Strip is estimated at 54 mcm where the current irrigation water supply is estimated at 162 mcm/y (90 mcm in the West Bank and 72 mcm in the Gaza Strip [1].

In the last two decades, the deficit between available water resources and the growing water demand in the Gaza Strip has been complicated by other exploitation of the shallow aquifers and limits placed on development. In the West Bank increasing demand has been obstructed by the Israeli authorities by restricting the water quantities allocated for agriculture to those of 1967.

Future water consumption is expected to increase rapidly due to the following reasons:

- The expected increase in population due to normal growth
- A rise in the standard of living of the Palestinians, which results in increase in demand per capita. Where the consumption per capita in Israel is 75 m^3, it is 30 m^3 for the Palestinians.
- With the peace settlement in process, thousands of Palestinian refugees and others who left the country in 1967 are now expected to return home.
- It is expected after the Palestinians take the responsibility for water sources that all the Israeli restriction on Palestinians from using their water will be no longer applied. So the availability of water will be increased which will lead to increase in water consumption.
- Due to the security that the Palestinians will feel, most of Palestinian investors will invest in Palestine. This will lead to heavy water consumption, especially in industry.
- Due to the growth of Palestinian and returnees, more food will be required for the Palestinians. This will imply planting additional areas where irrigation is playing a major role. This will lead to an increase of agricultural water consumption.
- Another reason for increasing agricultural water consumption is job creation, where Palestinian returnees will work in agriculture. Irrigated agriculture will be the main job provider.
- In addition to that, Palestinians will plan to build their economy. Irrigated agriculture is a major element in the economy of Palestine.
- Many researchers have estimated future domestic water consumption. Al Khateeb [1] estimated the total domestic water consumption in the year 2020 to be in the range of 571–726 mcm. More details are presented in Table 4, while Shuval [7] estimated the total water consumption to be 625 mcm in the year 2020. More details are given in Table 5.

On the other hand, agricultural water consumption as well as additional irrigated areas are estimated by various researchers. Hadad [3] estimated the total irrigated water consumption in the year 2010 in the West Bank to be 205 mcm, while the total irrigated area will be 200,500 dunams. For more details see Table 6.

While Al Khateeb estimated the potential of irrigated area estimated to be 712,000 dunams in Palestine where agricultural water consumption is estimated to be 500 mcm/y, assuming 700 m^3

Table 4
Water demand projections with population growth in Palestine

Year	Expected population including returnees		Per capita consumption, m^3/y	Increase in consumption	Total domestic demand, mcm	
	Low	High			Low	High
1992	1,800,800	2,149,000	67	—	121	144
2000[a]	2,930,000	3,722,000	84	3	245	313
2010[b]	3,750,000	4,760,000	110	2.75	412	524
2020[b]	4,571,000	5,809,000	125	1.25	571	726

[a]Includes 25 m^3 for house farming.
[b]Population projections include natural increase plus expected returnees.

Table 5
Population and water consumption [7]

	Palestine		Israel	
	2005	2020	2005	2020
Population (millions)	3	5	7	10
Water use (mcm/y)	375	625	875	1250

Table 6
West Bank water needed for agricultural consumption [3]

	1990	2010[a]	2010[b]
Irrigated area/dunums, 000	104	95	200.50
Vegetables	50	62	167.5
Fruit and citrus	54	23	23
Water consumption, mcm	84.79	110.5	205.45

[a]Political situation will remain the same (worst case).
[b]People implemented, establishment of Palestinian State (positive case).

dunams is needed. These figures imply that the total water demand by the Palestinians will be not by less than 1000 mcm provided that the rainfall, which is the main water source, is fairly constant where the total renewable water is estimated to be 700 mcm, leaving a minimum deficit of 300 mcm in the year 2020. This means that Palestinians should soon look to new water sources. The 700 mcm is on the assumption that Palestinians will have control over their water. Recycling of treated wastewater for irrigation will be the first option to provide enough water for the Palestinians.

3. Wastewater collection in Palestine

Sewage collection systems have been expanded recently to cover most of the urban areas. The municipalities bear the responsibility for the development of waste water collection and treatment facilities. In the rural areas, there is no collection system, except in the village of Bir Nabala and Al Ram. In the Jerusalem district, which is only partially served, there are two other sewage collection systems outside urban areas in Jabalia and Beit Lahia in the Gaza district. The rest of the population, especially in rural areas and refugee camps, uses cesspools and septic tanks.

Still wastewater collection does not completely serve the major cities, e.g., in Ramallah and Al Bireh only 75% of the population is connected to sewers; on the other hand, sewage collection is implemented now in Bethlehem, Beit Sahour, and Beit Jala as well as Ayada, Assa and Dheisha camps in the West Bank and Rafah in Gaza (for

Table 7
Cities connected to sewers and treatment plants

City	Availability of sewers TP	Date of implementation	Remarks
Ramallah	80% areated lagoon	1974	The efficiencies 20% studies have been completed for expansion.
Jenin	50% areated lagoons	1994	The expansion of the existing oxidation started early 1994.
Tulkarem	50% settling ponds	1972	Studies under preparation for modernization.
Qalqilia	50%	1975	—
Nablus	75%	1980	As yet no plans for treatment.
East Jerusalem	85%	1960s	—
Hebron	65% primary sedimentation	1993	The treatment plant is not yet perfectly functioning.
Bethlehem	100%	1993	Sewage collection expected to be completed in 1996.
Jericho	—	—	—
Salfit	—	—	Studies and design were completed in 1993. Implementation is imminent.
Bir Zeit–Jefna	—	—	Studies and design to be completed in July 1994.
Gaza	75% aerated lagoons	1980	Treatment plant constructed in 1990s.
Jabalia	50% aerated lagoons	1976	Aerator still not installed.
Rafah	10%	—	The EU began implementation of the sewers in 1994.
Khan Younis	—	—	There are plans for treatment and collection, and sewage collection was begun, but the Israeli military officials obstruct the project.

more details see Table 7). It is estimated that only 20% of all the population is served. Wastewater from villages and rural areas is discharged into individual cesspools where it seeps down to groundwater aquifers causing pollution problems.

While most of the wastewater from the cities that are served by sewers is channelled through pipes to the outskirts or to nearby wadis, few wastewater treatment plants have been implemented in few cities (Table 7). All the treatment plants are oxidation ponds except for an aerated lagoon plant in Ramallah and in Gaza City.

The effluent from these plants is channelled to the wadis; the quality of the effluent is still a problem (e.g., the effluent BOD of the Ramallah plant is over 300 mg/l. This effluent is flowing and percolating down to the aquifer causing ground water pollution.

4. Problems of the existing wastewater

Wastewater seeps and infiltrates down from the individual cesspools to the groundwater aquifers causing groundwater pollution as well as spring pollution. The Sinjel spring in the Ramallah area is an example. Zbeidat village in the Jordan Valley is another example where the village houses surround the village groundwater well. This well was used for agriculture while in 1992 the villagers started to use this well for domestic purposes (due to the Intifada). Some skin rashes cases have been reported in the Zbeidat village. This disease is due to polluted water. There is evidence that groundwater has been polluted especially in the Jordan Valley.

Since this waste water is flowing over soil surface, in the long run salt accumulation as well as suspended solids will destroy the texture and the structure of the soil and consequently reduce the fertility and productivity of the soil.

Unfortunately, some farmers are using the raw sewage to irrigate their vegetables, such as Deir Sharaf farmers in the Nablus area and Obedia farmers in the Bethlehem area, since raw sewage is flowing in an open canal. This is a serious health hazard. The best example is the cholera attack in 1970 in Jerusalem. In a health study in the Nablus region from 1981–1984, 32.2% [3] of 22,970 samples indicated that there is intestinal parasitic disease. Amoeba was consistent with 71% of all intestinal parasitic diseases while ascares represents 18%. They were considered the main cause for diarrhea in children and other diseases. The main transfer of these parasites is either through consuming polluted vegetables or drinking polluted water.

Unfortunately animals used to drink the raw sewage and graze on the weeds that grows near the path of the water. Hence diseases will be transmitted to people through drinking the milk and eating the meat of these animals.

Another negative impact of the flowing of raw sewage in open channels is deterioration of the domestic water pipes as is found in the Balata camp (near Nablus) where raw sewage is flowing in an open channel so that the domestic piped water system has deteriorated. Due to this deterioration as well non-continuity of pumping, negative pressure was created. This was found in 26 out of 27 samples from the tap in one house. In that camp fecal coliform is present and these 26 samples are polluted according to WH0 standards. It was found that the number of fecal coliform in five samples was more than 1000 per 100 ml [3].

Children play in this raw sewage which will transmit diseases to them. In addition, insects find in this sewage a good place for living and breeding, and hence can easily transmit diseases to human beings.

The smell and odor of this sewage create a bad environment for people, especially children, and complicate the life of the population.

5. Development of wastewater

The existing condition of wastewater is considered to be disastrous for Palestinians, especially in the long run. Groundwater, especially in the Jordan Valley at the depth of the existing wells is in the range of 40–60 m. In addition to that, the wastewater of Nablus, Al Bireh, Jerusalem, and Bethlehem is flowing to the east where chemical and biological tests proved that there is contamination in groundwater wells where the number of fecal coliform reaches 90 per 100 ml in groundwater wells in Jericho.

Even this water through seepage is considered as recharge to the aquifers, but people should pump this polluted water where treatment of this water should be when this water will be used for domestic use (additional cost of pumping and treatment).

Treatment of this wastewater will have the following benefits: (1) eliminate health hazards, (2) protect ground water pollution, and (3) reduce the cost of treating groundwater wells for domestic purposes. In addition, another major benefit can be created when this treated wastewater is recycled for irrigation purposes (discussed in

detail below) such as

- Increase the irrigated area in Palestine which will lead to improving the economy
- Create additional jobs
- Provide enough water for domestic purposes
- Reduce water shortage problems
- Generate income to cover the O&M of the treatment by selling the treated water for irrigation purposes.

6. Obstacles that face implementing sewage collection and treatment plants

As stated before, all of the 351 villages in the West Bank lack wastewater collection; even some major cities and camps in the West Bank and the Gaza Strip lack sewage collection pipes such as Jericho, Salfeet, Bir Zeit in the West Bank and Nissirat, Abasan, Deir El Balah and Karara in the Gaza Strip.

Treatment is only available in four cities where the operation and maintenance is not enough, causing the efficiency of the treatment to be very low. Wastewater collection and treatment projects are considered the "forgotten infrastructure projects" due to the following obstacles:

1. High cost of investment needed — Since municipalities bear the responsibility for sewage collection and treatment, it is very difficult for the individual municipality to raise the required funds for the capital cost which is needed for such projects. For example, the estimated cost of sewage collection and treatment is $8 million for Halhul City, while the estimated cost of construction of a treatment plant (an anaerobic pond followed by an aerated lagoon) in Ramallah as well as a seasonal reservoir and 6 km pipe to the irrigated area is $7 million, excluding the cost of land. Al Khateeb [1] estimated the investment cost per capita for collection to be $220 and $180 for the West Bank and Gaza, while for treatment it is $80 and $40, respectively. Table 8 summarizes the capital cost needed for wastewater treatment infrastructure. The cost varies due to the following:

Table 8
Investment needed for wastewater reuse infrastructure [1]

Year	Urban population and refugees		Agricultural cost (millions of dollars)	
	Low	High	Low	High
1992	1,080,000	1,280,000	324	381
2000	1,758,000	3,233,000	527	670
2010	2,250,000	2,859,000	675	658
2020	2,743,000	3,485,000	823	1038

- In some cities a pumping station is needed; in Ramallah eight pumping stations were installed while in Bir Zeit, Jifna, Ein Sinia no pumps are needed
- Type of wastewater treatment
- Dense population, where it is clear in the above that sewage collection estimated cost in Gaza is less than in the West Bank.

2. Influent quality — Since this influent is going to be recycled, the effluent quality should meet the WHO standard in order to eliminate a health hazard. The high influent BOD (800 mg/l) (personal experience) as well as the high fecal coliform (107/100 ml) raise the capital cost of treatment and demand for large area of land for treatment. This high BOD and others is due to low water consumption.

3. The lack of authority that will manage industrial connection to municipal wastewater causes the presence of heavy metals and chloride; Table 9 shows the chemical and biological tests of the existing aerated lagoon wastewater treatment plant in Ramallah.

4. Topography of Palestine (especially the West Bank) due to the geological formation of the West Bank (wadis, mountains) which limits the use of low technology cost wastewater treatment plants such as waste stabilization ponds. For example, in El Bireh it took the city 1 y (aerial photo has been taken) to investigate the possibility of using waste stabilization ponds as

Table 9
Water quality of the existing Ramallah wastewater treatment plant

	Sample sites				
	B	C	D	F	G
Cl, mg/l	304	419	319	284	318
Ca, mg/l	72	48	81	103	75
Mg, mg/l	52	46	31	31	38
Na, mg/l	150	233	203	166	176
pH	7.76	7.5	7.72	7.61	7.6
E. coli, ms/cm	2	2.96	2.09	2.16	2.14
Boron, mg/l	2	2.5	2	1.5	1.65
SAR, mg/l	3.28	5.73	4.8	3.5	4.13
BOD	800	400	350	300	300

Note: The BOD is the average of different samples.

Diagram of the treatment plant, No. 1

B: Influent	C: Aerators	D: Stabilization pond	E: Stabilization pond	F: Effluent

low technique, i.e., low capital and operation costs. The results were the adoption of high-tech (description given below), which required a large investment as well higher operation and maintenance costs per m^3. In addition, the operation is more complex.

6.1. Quantities of wastewater available for reuse

Simply, the average water consumption estimated to be in the year 2000 will be 90 l per capita/d, and the population is expected to be around 2.3 million. Therefore, 90 l/1000 × 2,300,000 = 208,000 m^3/d = 75,555,000 mcm/y where only 70% of this water can be recycled due to evaporation and other losses; thus the available wastewater for reuse (provided sewage collection and treatment are serving all Palestine cities, villages and camps) is 52,888,500 m^3/y. Other estimations are shown in Table 10 [1] and Table 11 [3].

Available wastewater from the major cities can be estimated as follows: 1.2 million in 1991 (Table 11) ×80 l/c/d×365 d= 35 mcm, of which 70% can be recycled; i.e., 24.7 =25 mcm, while Shuval [7] estimates that by the year 2023, the Palestinians could have as much as 325 mcm per year of waste water.

6.2. Benefits from recycling of wastewater for irrigation

- Generation of additional irrigation area — Since 25 mcm can be available from the major cities only for irrigation, where 7OO m^3 is the irrigation regiment per dunam (average demand where jojoba, fodder crops can be used), so an additional 35,000 dunams can be created. This is a major success provided that the total existing irrigated area is about 210,000 dunams. This number of dunams can grow due to (a) an increase in population due to normal growth rate, (b) an increase in water consumption per capita and (c) many Palestinian returnees.

Table 10
Quantity of wastewater potentially available in the West Bank and Gaza Strip [1]

Year	Population of West Bank and refugee camp		Domestic communication, cm/c/y	Waste available for reuse, 65% of domestic consumption	Potential wastewater, mcm	
	Low	High			Low	High
1992	1,080,000	1,289,000	67	43	47	56
2000	1,758,000	2,233,000	84	54	96	122
2010	2,250,000	2,859,000	110	71	161	204
2020	2,743,000	3,485,000	125	81	223	283

Table 11
Total wastewater generated from the major cities in the West Bank and Gaza [3]

Municipality area	Population			Wastewater		
	1991	2010 A	2010 B	1991	2010 A	2010 B
Jerusalem	73,036	141,922	422,891	1,068,411	2,505,806	12,700,347
Nablus	145,810	280,265	835,117	2,109,879	4,948,421	25,080,401
Hebron	90,055	173,097	515.784	1,303,101	3,056,239	15,490,128
Ramallah	52,000	99,950	297,872	782,443	1,674,739	8,944,400
Tulkarem	49,610	95,357	284,138	717,860	1,681,879	8,533,290
Jenin	39,238	75,420	224,733	567,776	1,331,632	6,749,225
Bethlehem	69,309	133,220	396,963	1,002,905	2,352,162	11,921,672
Jericho	14,265	27,419	81,802	206,415	484,116	2,453,691
Gaza	349,154	668,380	128,245	10,833	15,552	29,840
D. Al Balah	98,088	187,708	408,041	3,043	4,370	9,494
Khan Hounis	131,617	251,952	423,796	4,083	5,863	9,861
Rafah	97,141	185,955	359,202	3,014	4,327	8,358
Total	1,219,123	2,320,705	5,532,615	809,665	1,815,510	9,196,070

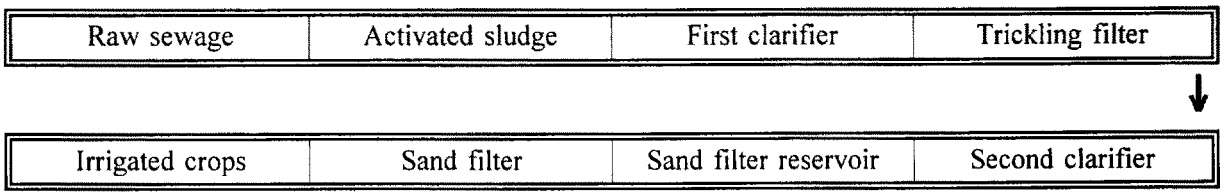
- Job creation — Since at least 35,000 dunams will be irrigated, where most of these areas will be planted with jojoba, fodder crops, trees, etc., the minimum requirement per 10 dunams is one worker so that 3500 new farming jobs will be created in irrigated areas. In addition, hundreds of workers, technicians and engineers are required for the operation and maintenance of new wastewater treatment plants, as well as agricultural engineers. The estimated number of jobs likely to be created is at least 1000 for the major cities alone. Thus the total minimum additional jobs are estimated at about 4500.
- Provide more fresh water for domestic use at less cost and higher health standards.
- Treatment and reuse of the wastewater will eliminate health problems and groundwater pollution.
- Wastewater is considered to be rich in nutrients and hence there is little or no need to use fertilization which will eventually reduce the cost of farming (for more details see [10]).

Table 12
Water quality of El Bireh wastewater pilot plant

Sample site	FC, 1100 ml	TS, g/l	SS	Na, ppm	Total *n*, ppm	BOD, mg/l
Raw sewage	9×10	0.180	0.136			450–500
After second clarifying	7×10^6	—				
Sand filter reservoir	0.0	2.69	2.152			
Effluent	4.1×10^5 7.6×10^6	0.88	0.32	93	27	20–60

Notes: BOD is a bit low since the industrial zone is not connected. FC in the sand reservoir, wastewater stored for 6 days.

Diagram of the treatment plant, No. 2



6.3. Wastewater treatment and reuse pilot plant in El Bireh municipality

Al Bireh Municipality planned in 1990 to establish its own wastewater treatment plant. The plan was at the first stage to use a waste stabilization pond, but due to the topography situation, activated sludge followed by trickle filter was adopted; to investigate this idea, a pilot plant with a 8 m^3/d capacity was constructed in July 1993. The influent and effluent are shown in Table 12, and the structure of the plant is shown in Diagram 2.

The municipality thought of planting crops using the treated effluent. This was funded by American Near East Refugee Aid (ANERA). Three crops were selected by the Agriculture Department to be planted for the first time in Palestine using treated wastewater:

- Artichokes on 150 m^2 — planted on October 31, 1993
- Onion freezed production on 500 m^2 — planted on November 6, 1993
- Wheat on 1000 m^2 — planted on November 22, 1993.

Drip irrigation as well as sprayers were used.

Several treatments were made as follows:

1. Irrigation with wastewater used, fertilization was used.
2. Same as above, but without application of fertilization.
3. Irrigation not used but fertilization was used.
4. No irrigation and no fertilization (dry land farming).

All the agricultural practices were used (pesticides, ploughing, seed control, etc.)

Table 13 shows the production of each kind of treatment. The impact of using treated wastewater appears clear.

7. Conclusions and recommendations

1. Running water still is not available in 56% of the rural areas in the West Bank, so planning piped water should be implemented soon to

Table 13
Results of El Bireh wastewater treatment pilot plant using treated wastewater

Treatment	Production of wheat (anber variety), all the plants, kg/dunum
• Irrigation with treated wastewater with fertilization	2520
• Irrigation with treated wastewater without fertilization	2036
• Without irrigation, with fertilization	1600
• Without irrigation, without fertilization	572

Notes:
1. Time of planting was October 1993; all the crops received rainfall during the growing period.
2. Time of harvesting was June 2, 1994.
3. Production with irrigation with treated wastewater with fertilization was five times without irrigation and fertilization.
4. Production increased the soil when irrigated with treated wastewater where fertilization was applied on both cases (irrigated and non-irrigated).

improve the standard of living for the population.

2. Wastewater collection is only available in the major cities, and in some cities it is only partially available. Only about 25% of the population is served by sewers, and there are only four wastewater treatment plants in the country.

3. Planning should be implemented soon to serve the whole country with sewers and treatment plants. Plants should be of low technology to minimize the cost of O&M as well as to guarantee ease of operation.

4. Villages, cities and camps that are geographically close should plan together to establish common treatment plants in order to minimize the capital and O&M cost. Bir Zeit, Ein Sinia, Jifna, Al Jalazon and the Dora Al Qareh project, which is in the design stage, is one example.

5. Funding is the main obstacle for these infrastructure projects. The Palestinian National Authority should plan to allocate the funds needed. These projects should be covered financially by the Israeli government since Palestinians pay taxes to Israel.

6. Some industries should not be connected with the municipal sewers in order to minimize the presence of toxic and heavy metals.

7. Palestinians should have their own plans for treatment and collection in order to get benefit from the treated wastewater.

8. The potential of reusing the treated water for irrigation purposes is available, and this will be of a great benefit to the Palestinians where at least an additional 35,000 dunams can be irrigated from the wastewater of the major cities.

9. Palestinians should focus on planting crops such as alfalfa, industrial crops such as jojoba, and seed production such as onion to avoid the health problems where there is a good local market for these crops.

10. Training programs to run wastewater plants should be started soon, as well as for farmers and agronomists in the field of recycling.

11. Public education and awareness should be carried out to discuss the idea of reuse to the public to clear the idea.

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