Socio-Economical and Environmental Impact for the Agricultural Use of Wastewater in the Wadi Nar Catchment/ Dead Sea Region

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Abstract

A total of 237 questionnaires were filled out and analyzed for farmers and consumers in Wadi Nar catchmnet for the socio-economic impact of using the treated wastewater for agricultural purposes. The majority of the respondents replied that there is a shortage of water in the area and they suffer as a result in their households. Health and environmental risks were anticipated to be the two major concerns in both cases. The majority of the respondents are willing to use restricted water for irrigation but were reluctant on using unrestricted water for the same purpose. About 79% of the respondents replied that they were not willing to use unrestricted wastewater in case there is no fresh water. About 66% of the sample do not pay anything for disposing their wastewater while the average cost for those who do is about 473 NIS/year ranging from 50 to 1600. It can be concluded that damage to the groundwater and the economy are not major concerns in both cases with health risks are thought to be a threat to many whether treated or not. Respondents believe that the main factor that influences the consumption of products irrigated with treated wastewater is the fear from health risks. More than half of the respondents refuse to pay for fruits and vegetables irrigated with treated wastewater. The average of the BOD and COD in sampled wastewater is 185 and 320.6 mg/L respectively which reflect the dangerous impact of using this wastewater for irrigation. These amounts reflects there harmful effect of their use in irrigation. According to SAR average of 19.4, the irrigation of wastewater will cause harmful effect to the consumers of the plants and crops when it is used for agriculture. This results matches with the result of both the analyzed questionnaires of farmers and consumers.

Keywords: Wadi Nar, Socio-economic, wastewater

1.Introduction

The deterioration of the environmental situation in the West Bank and the high water scarcity level needs for an immediate action for the treatment of raw sewage and the upgrading of existing over loaded treatment plants. Wastewater reuse will also play an important role in the re-allocation of scarce water resources among sectors of the economy. The development of a sustainable and affordable wastewater treatment system will have a positive impact on the Palestinian economy through poverty alleviation. The wastewater sector in the West Bank is characterized by poor sanitation, insufficient treatment of wastewater, unsafe disposal of untreated or partially treated water and the use of untreated wastewater to irrigate edible crops. Whether in urban or rural areas, the reuse of treated wastewater is practiced on a small scale and this option has been generally absent from wastewater treatment plans. However, few studies have examined the overall picture of wastewater treatment and reuse in WB, particularly inclusive of rural areas, in order to derive key priorities for actions at the strategic level and identification of practical pilot studies to be carried out. Wastewater is a very significant pollution source that has serious adverse impact both on the environment and local residents. In the Palestinian Territories raw wastewater is disposed in wadis or left to infiltrate through cesspits into the underlying vulnerable groundwater. Many, especially in marginalized rural areas, leave the wastewater to simply seep into the streets inducing bad odors, spreading insects and possibly causing diseases.

The main objective of this study is to study the socio-economic analysis of the wastewater reuse and their impact on the inhabitants that are living in the suffered areas and their impact on the environment and how the results would affect the related policies.

A Socio economical overview about Collection, treatment and reuse costs, Willingness to Pay, Affordability & Cost Recovery, Costs of Fresh Water and the Potential Benefits of the people in the study area is defined. The polluted sources in the southern part of the Jordan Rift Valley, especially in the Nar Wadi area were determined. There are major real potential health, environmental and economic impacts as a result of poor sanitation, improper disposal of treated and untreated wastewater, and use of raw or partially treated wastewater to irrigate edible crops.

The Wadi Nar catchment is one of major surface water catchments in the southern region of the West bank located with regard to the Palestinian grid references as: 169.830 – 193.720 E and N 108.850 – 134.080 (Figure 1). The catchment extends from Jerusalem in the west to the Dead Sea shoreline in the East. The watershed is triangular shaped with the area of 199 km^2, which accounts for about 3.5% of the West Bank. It overlies two districts of the West Bank, these are Jerusalem and Bethlehem and it includes twenty seven communities. It covers a wide range of different landscapes and topographic environments. The western section falls steeply at first and then flattens out for about 10 km to terminate in a steep escarpment at the edge of the Dead Sea with a distance of 30 km. Its topographic relief changes from 800m above sea level in the western edge near Jerusalem to less than 375m below Sea level in the east.

This basin drains sewage of the southern part of Jerusalem including the old city, the new community of Al Qhnaim, parts of Bethlehem, Beit Sahour, and Alubeidia, Al Khas and other Bedouins communities. Some of the 28000 cubic meters per day of raw wastewater flow to collection facilities near the Dead Sea where they undergo primary treatment (settling only) and are utilized for irrigation of palms (EQA, 2009). Domestic wastewater in Jerusalem is collected in pipes within the residential areas and from there it flows freely in open channels. The wastewater flows from urban areas, by gravity, through wadies.

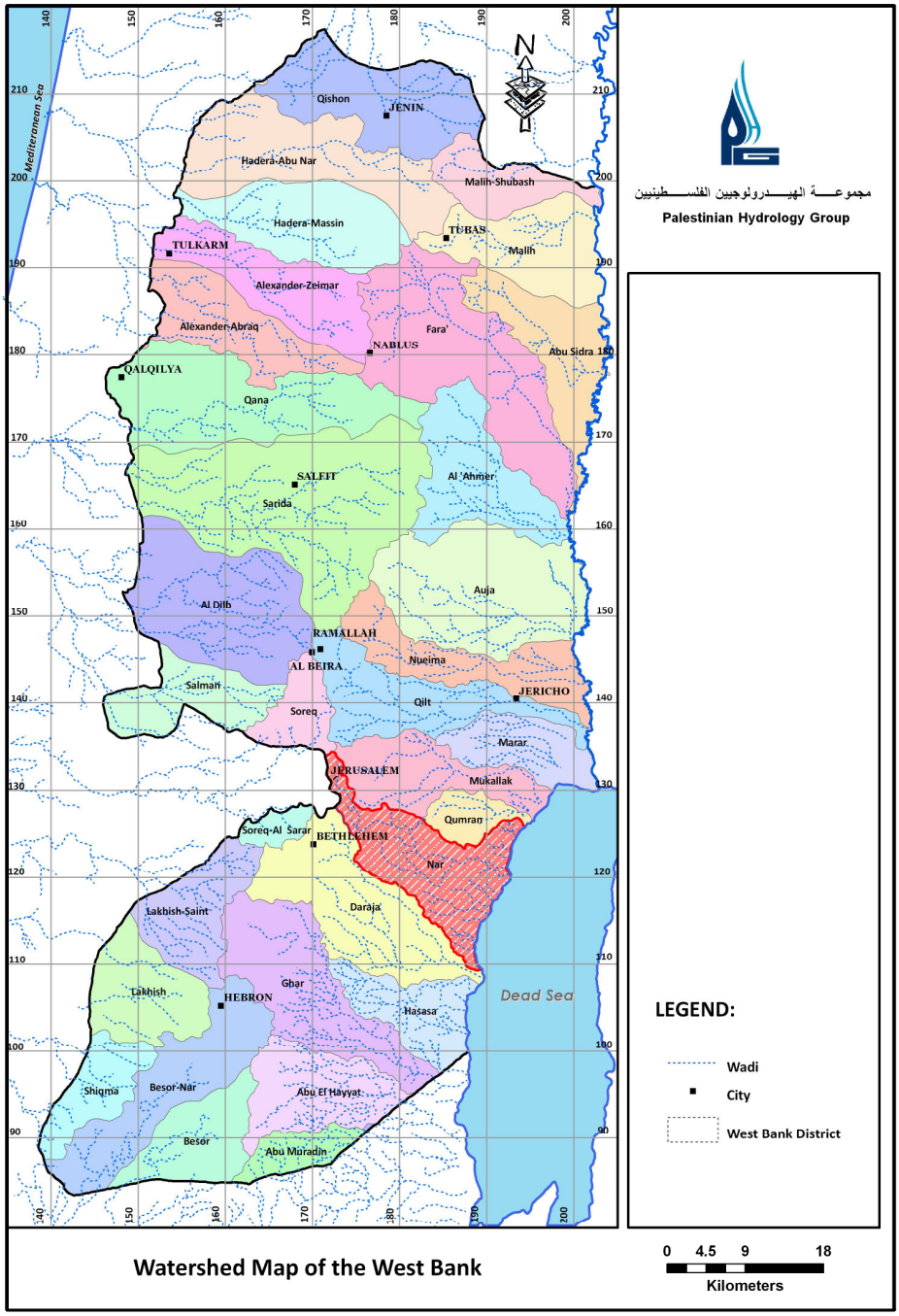


Figure 1: The location map of the study area

2. Material and Methodology

Several field visits were conducted in the area of Wadi El Nar in the western slopes of the Dead Sea in order to put the criteria needed for the factors that area affecting the socio economy of the adjacent living people in the area. Two socio economic questionnaires were designed and distributed in the Wadi Nar area. The collected and filled questionnaires were analysed using the SPSS in order to interpret the questionnaire results. A wastewater sampling campaign was conducted in the Wadi Nar catchment in the period between April - May 2009 from the main wadi discharge.

The sampled wastewater were analyzed at the lab of BZU in Ramallah for the analyses of BOD, COD, TSS, TDS, EC, Salinity, Calcium, Magniesum, Kalium, Natrium, Phosphorus, and Nitrate concentrations.

3. Results and Discussion

3.1 Socio- economic

Socio economic results were obtained from the analyzed questionnaires of the farmers that have some kind of agriculture in the adjacent areas of the wadi Nar. A total of 120 questionnaires were filled out in the targeted areas in both the Governorates of Bethlehem and Jerusalem, as shown in Table 1.

Table 1: Geographical distribution of questionnaires for farmers

Locality	Governorate	Frequency	Percent
Dar Salah	Bethlehem	2	1.7
Al Ubeidiya	Bethlehem	106	88.3
As Sawahira ash Sharqiya	Jerusalem	12	10.0
Total	-	120	100.0

A total of 117 questionnaires were filled out in the targeted areas in the Governorate of Bethlehem, as shown in Table 2.

Table 2: Geographical distribution of questionnaires for consumers

Locality	Frequency	Percent
Dar Salah	30	25.6
Al Ubeidiya	84	71.8
Bethlehem	1	0.9
Beit Sahur	2	1.7
Total	117	100.0

3.1.1 Socio-economic description of respondents

About half of the farmers respondents are 45 or older with only 7.5% between 16 and 24. Analysis results show that the majority of the respondents are males and the majority of the sample is married, it was also noticed that a considerable portion of the sample has a family size of 8 members or more. The questionnaires also revealed that the vast majority of the respondents are permanent residents and do not leave their dwellings at all. The vast majority of the sample has a moderate level of education. Three quarters of the respondents fall in the age category between 16 and 24 years old with only 4% older than 45. Noting the important role that the Palestinian women play in their households in both the management of water resources and purchasing food supplies about 70% of the respondents were females as indicated. The majority of the sample is single and for those married the average number of children is 4. The vast majority of the sample has at least a secondary level of education. The respondents were widely distributed among the income categories defined in the questionnaire.

3.1.2 Water Consumption and wastewater

The majority of the farmer respondents replied that there is a shortage of water in the area and they suffer as a result in their households,. Almost 69% of the respondents pay less than 500 NIS/year for emptying their cesspits. The majority of the respondents are land owners. According to the consumers respondents the average water consumption of the families is estimated to be 22 m^3/month with an average monthly water bill of about 134 NIS. More than half of the respondents suffer from the shortage of water supplied through the public network as a result many of them own rainwater harvesting cisterns, with an average capacity of 50 m^3. Only a minor portion of the sample purchase water from water tankers as a supplementary source with annual costs ranging between 100 and 1000 NIS/year at an average of 433. It was noted from the questionnaire that a considerable portion of the respondents irrigate their home gardens with fresh water.

3.1.3 Farmers Area of cultivated land

Most of the respondents cultivate a total land area between 1 and 5 dunums, while it was reported that less than 1 dunum is irrigated. Analysis shows that the most common water source used for irrigation is the public water network (used for demostic purposes), noting that a considerable portion use untreated wastewater (direct from the Wadi Nar). The The average fee paid for water for agricultural purposes is 4 NIS/m^3 ranging from 0, which is only a minority to 5 while an average farmer uses an annual quantity of 136 m^3/dunum. The water is used to irrigate a variety of crop types.

3.1.4 Wastewater disposal

As in the majority of the communities in the West Bank the respondents use cesspits for the disposal of their wastewater as in figure 2. About 66% of the sample do not pay anything for disposing their wastewater while the average cost for those who do is about 473 NIS/year ranging from 50 to 1600.

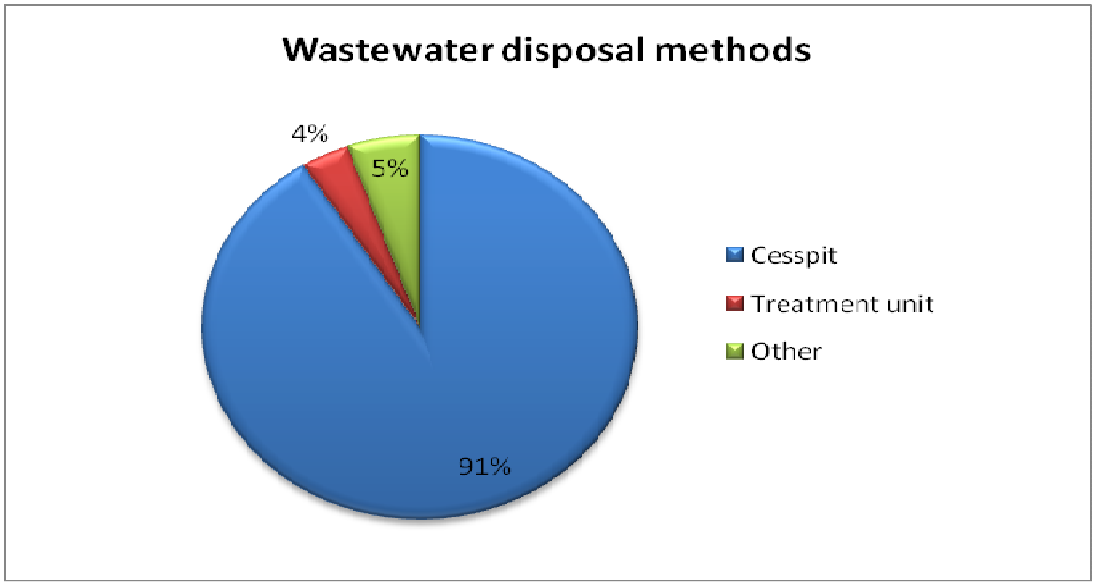


Figure 2: Household wastewater disposal method

3.1.5 Wastewater treatment and Reuse

Almost half of the farmers respondents thought that the main objective of treating wastewater is to avoid health risks. Tables 3 and 4 show the respondents' anticipation on the risks associated with using untreated and treated wastewater respectively for irrigation. It can be concluded that damage to the groundwater and the economy are not the major concerns in both cases with health risks are thought to be a threat to many whether treated or not.

Table 3: Risks associated with using untreated wastewater for irrigation

Risks	Yes	No
Health risks	85.5	14.5
Environmental risks	51.3	48.7
Agricultural damage	55.6	44.4
Soil damage	37.6	62.4
Groundwater damage	22.2	77.8
Economic damage	22.2	77.8

Table 4: Risks associated with using treated wastewater for irrigation

Risks	Yes	No
Health risks	80.2	19.8
Environmental risks	44.0	56.0
Agricultural damage	37.9	62.1
Soil damage	31.0	69.0
Groundwater damage	17.2	82.8
Economic damage	28.4	71.6

Logically, the majority of the respondents replied that they are interested in knowing the source of water used for irrigation (Figure 3).

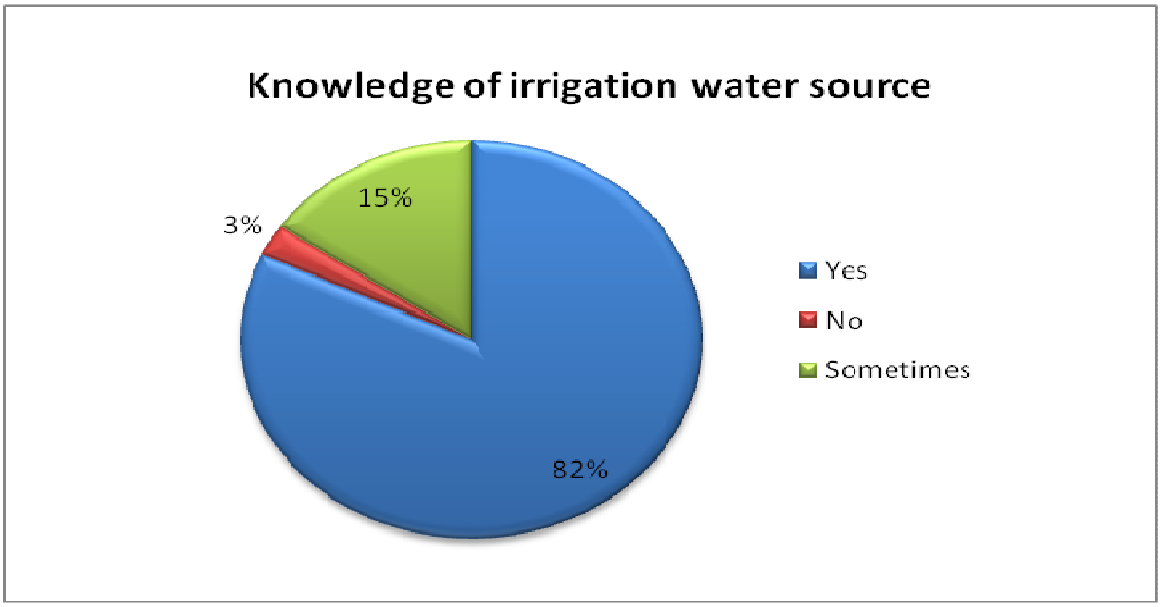


Figure 3: Interest in knowing source of irrigation water

Respondents believe that the main factor that influences the consumption of products irrigated with treated wastewater is the fear from health risks. More than half of the respondents do not reuse domestic water used for cleaning in irrigating their gardens.

Table 5 shows the reasons behind the respondents' hesitation for consuming products irrigated by treated wastewater mainly being that the farmers will not use the right quality of water.

Table 5: Reasons for not consuming products irrigated by treated wastewater

	Percent
Farmers will not use the right quality of water	36.4
Farmers will not follow the irrigation Safety Guideline	18.2
Lack of accomplishing duties by responsible authority	33.3
Inefficiency of wastewater treatment plant	7.1
Other	5.1
Total	100.0

More than half of the respondents refuse to pay for fruits and vegetables irrigated with treated wastewater (Table 6).

Table 6: Willingness to pay for fruits and vegetables irrigated with treated wastewater

	Frequency	Percent
Yes	49	41.9
No	68	58.1
Total	117	100.0

3.1.6 Wastewater treatment and reuse for farmers

Table 7 shows what the respondents thought was the main objective behind the treatment of wastewater, results show that the opinions were diverse.

Table 7: Objective of wastewater treatment

Objective	Percent
Does not accomplish anything	4.3
Avoid health risk	24.5
Saving fresh water	23.4
Keep a clean ecosystem	14.9
Economic reasons	12.8
Other	20.2
Total	100.0

Tables 8 and 9 show what respondents thought are the main risks associated with using untreated and treated wastewater for irrigation. Health and environmental risks were anticipated to be the two major concerns in both cases.

Table 8: Risks associated with using untreated wastewater for irrigation

Risks	Yes	No
Health risks	97.5	2.5
Environmental risks	72.5	27.5
Agricultural damage	34.2	65.8
Soil damage	20.0	80.0
Groundwater damage	36.7	63.3
Economic damage	16.7	83.3

Table 9: Risks associated with using treated wastewater for irrigation

Risks	Yes	No
Health risks	53.8	46.2
Environmental risks	16.0	84.0
Agricultural damage	2.5	97.5
Soil damage	3.4	96.6
Groundwater damage	15.1	84.9
Economic damage	2.5	97.5

Table 10 lists the factors that are accepted to influence the idea using treated water for irrigation. Respondents believe that the availability of fresh water is the factor that will affect the acceptance the most.

Table 10: Factors affecting the use of treated wastewater for irrigation

Factors	Percent
Fresh water availability	40.4
Cost of treated wastewater compared to fresh water	21.1
Willingness to buy products irrigated with treated wastewater	23.7
Health risks	11.4
Other	3.5
Total	100.0

About 43% of the respondents reuse the domestic water used in their households for cleaning purposes reuse it in irrigating gardens. The majority of the respondents are willing to use restricted water for irrigation but were reluctant on using unrestricted water for the same purpose. Almost two-thirds of the respondents are willing to reuse treated grey water for irrigation. It is worthy to note that more than half of the respondents are willing to pay for treated wastewater , while the majority believe that the fee should be less than that of fresh water for both restricted and unrestricted water. The average amount thought to be a suitable fee for treated water used in irrigation is 1 NIS/m^3 while the highest price the respondents were willing to pay for water used in irrigation averaged to an amount of 1.5 NIS/m^3. About 79% of the respondents replied that they were not willing to use unrestricted wastewater in case there is no fresh water.

3.1.7 Awareness

About two-thirds of the respondents know of the existence of measures and standards that restrict the reuse of wastewater for irrigation. The vast majority of the respondents believe in the importance of involving farmers in decision making and the importance of water and environmental awareness. About half of the respondents say that group meetings with specialists are the most efficient awareness mechanisms followed by visits conducted by agricultural guides. Unfortunately, most of the respondents, have never visited a farm irrigated with treated wastewater. In addition, many have never been targeted by an environmental awareness campaign.

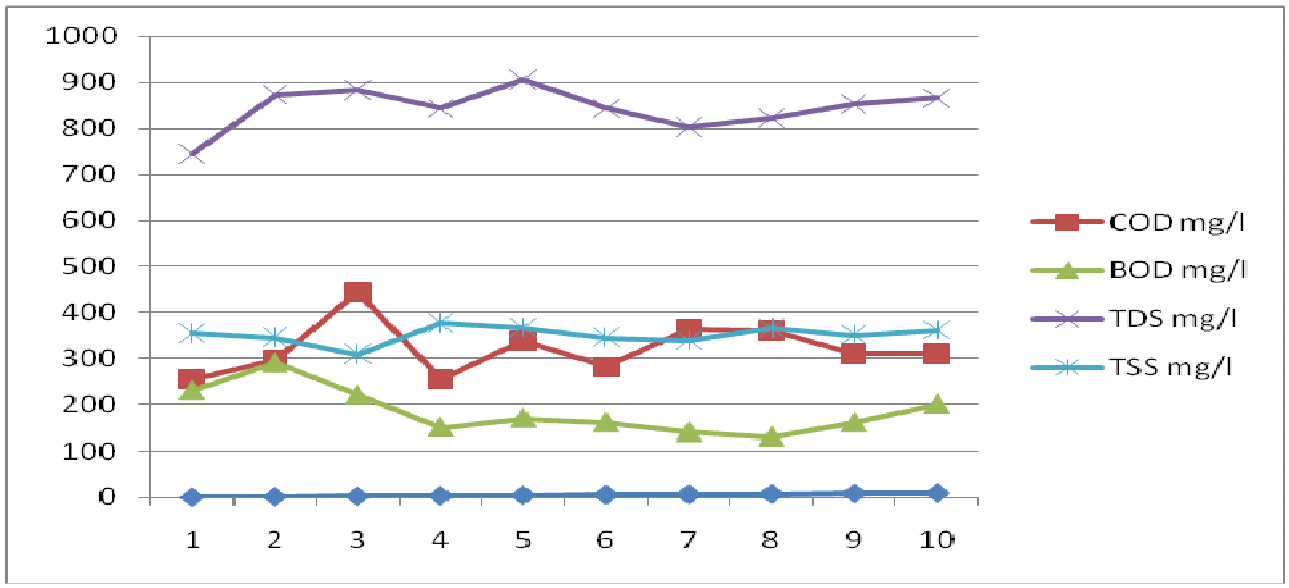
3.2 Wastewater Chemistry

A sampling campaign was conducted in the Wadi Nar area in April 2009. A total of ten samples were collected in order understand the chemical characteristics of the wastewater in the wadi. The sampled wastewater were analyzed at the lab of BZU in Ramallah for the analyses for the parameters of BOD, COD, TSS, TDS, EC, Salinity, Calcium, Magniesum, Kalium, Natrium, Phosphorus, and Nitrate concentrations. Table 11 shows the analyses of the wastewater samples of wadi Nar catchment of 3km length of the wadi around the main road to Bethlehem.

Table 11: The analyses of the wastewater samples of wadi Nar catchment.

Station Nr.	COD mg/l	BOD mg/l	EC µS/cm	Salinity %	TDS mg/l	TSS mg/l	NH3-N mg/l	TN mg/l	PO4-P mg/l	Ca mg/l	Mg mg/l	K mg/l	Na mg/l
1	253.3	230	1503	0.8	745	353	19.4	24.6	9.4	385	110	31	154
2	296.6	290	1784	0.8	873	344	23.4	29	11	338	122	22	172
3	443.3	220	1794	0.9	883	308	28	36	13.1	367	134	28	191
4	253.3	150	1703	0.9	843	376	20.3	24.4	10.4	328	108	14	133
5	336.6	170	1830	0.9	905	366	25.6	28.5	11.4	422	144	28	138
6	280	160	1720	0.9	843	344	18.2	24.8	9.8	355	116	33	165
7	363.3	140	1635	0.8	804	338	26.2	31.2	12.3	318	106	40	172
8	360	130	1666	0.8	823	365	25.6	33.1	12.1	334	118	48	166
9	310	160	1739	0.9	852	350	22.2	27.4	11.2	360	134	22	171
10	310	200	1755	0.9	865	360	21.8	25.8	11.4	378	142	30	163

The average of the BOD and COD in sampled wastewater is 185 and 320.6 mg/L respectively and ranges between 130 – 190 and 443 to 253 mg/L, respectively. Both amounts reflect the dangerous impact of using this wastewater for irrigation. The average of EC is 1712 µS/cm with a max of 1820 µS/cm. The average of the total dissolved solids is 843 mg/L with a range between 905 and 745 mg/L. The total suspended solids ranges between 376 and 308 mg/L with an average of 350.4 mg/L. These amounts are projected in Fig. 4 and reflects the high amounts of their concentrations and reflects there harmful effect of their use in irrigation.



4: The concentration of the BOD, COD, TSS and TDS in mg/L for the analysed samples.
The EC and TDS amounts changes of the analyzed samples pass together from place to place and show a decrease from the upstream to downstream directions (Fig. 5).

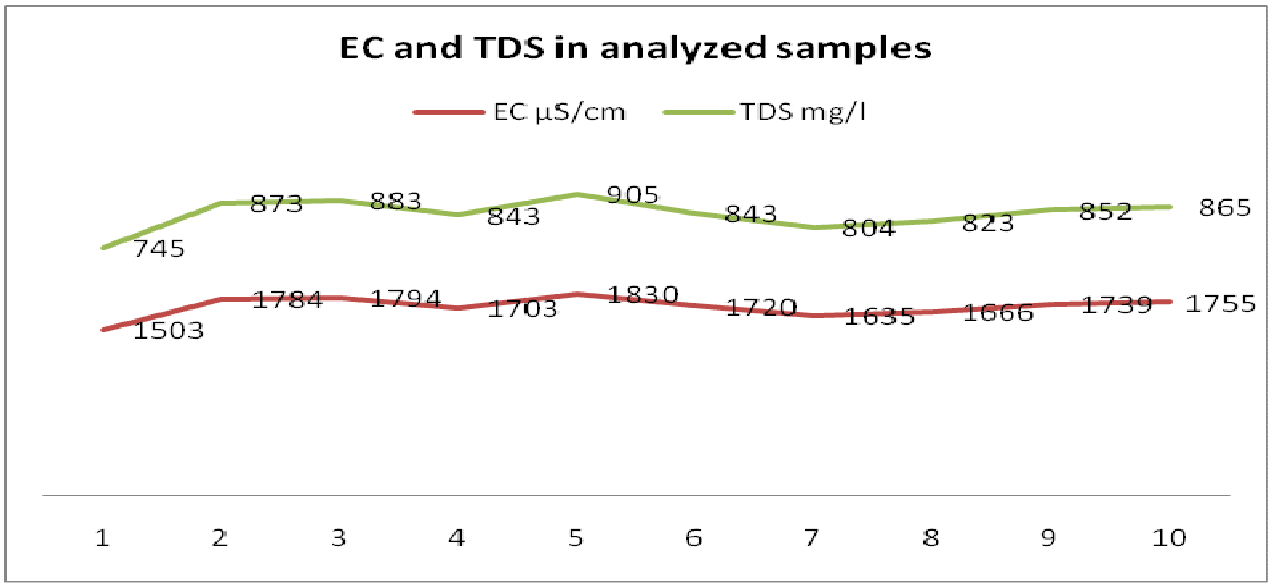


Figure 5: The TDS and the EC amounts of the analyzed samples.

The average of salinity of the analyzed samples in percent is 0.86 %, this reflects the large amount of salts that are containing in the Wadi Nar wastewater. The average concentrations of Ca, Mg, K and Na are 358.5, 123.4, 29.6 and 162.5 mg/L respectivley, while the average amounts of NH3, Total Nitrogen (TN) and PO4 are 23, 28.5 and 11 mg/L respectivley. The maximum and minimum concentrations are shown in Fig. 6 and 7.

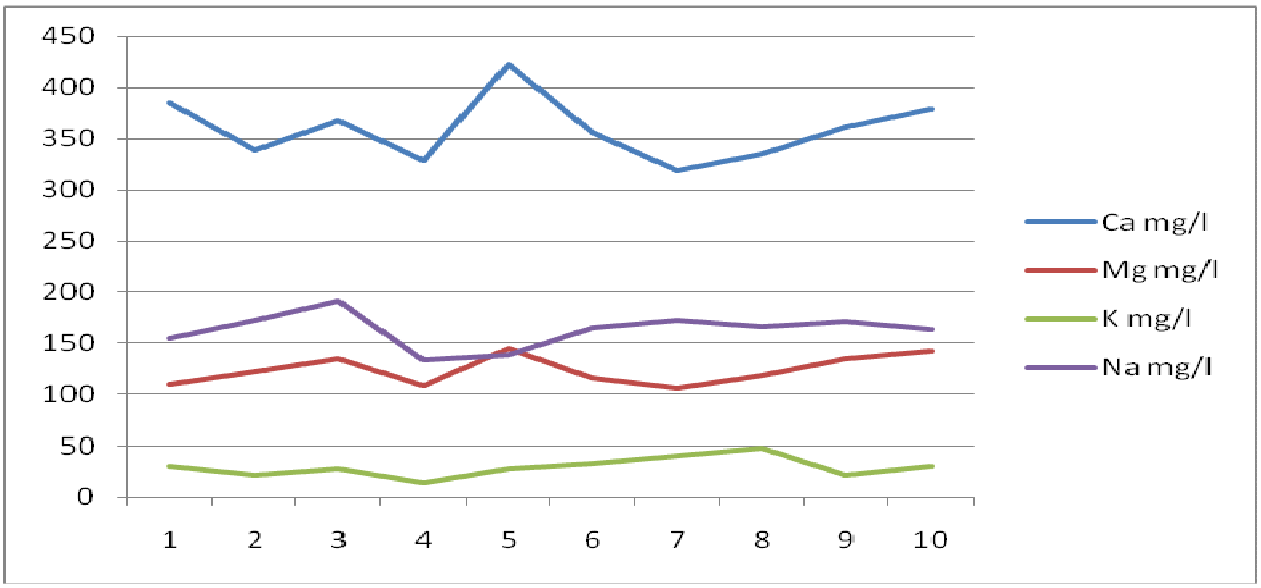


Figure 6: Ca, Mg, K, Na concentration in mg/L of wadi Nar wastewater

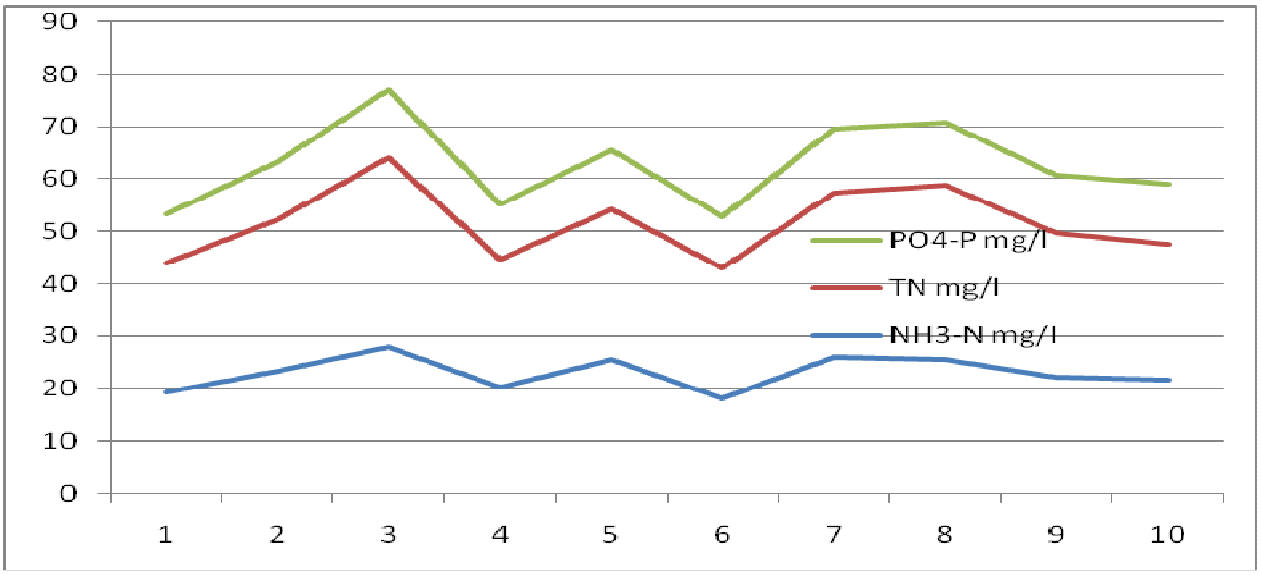


Figure 7: PO4, TN, and NH3 concentration in mg/L of wadi Nar wastewater

The linearity of the cations against EC is shown in Fig.7.

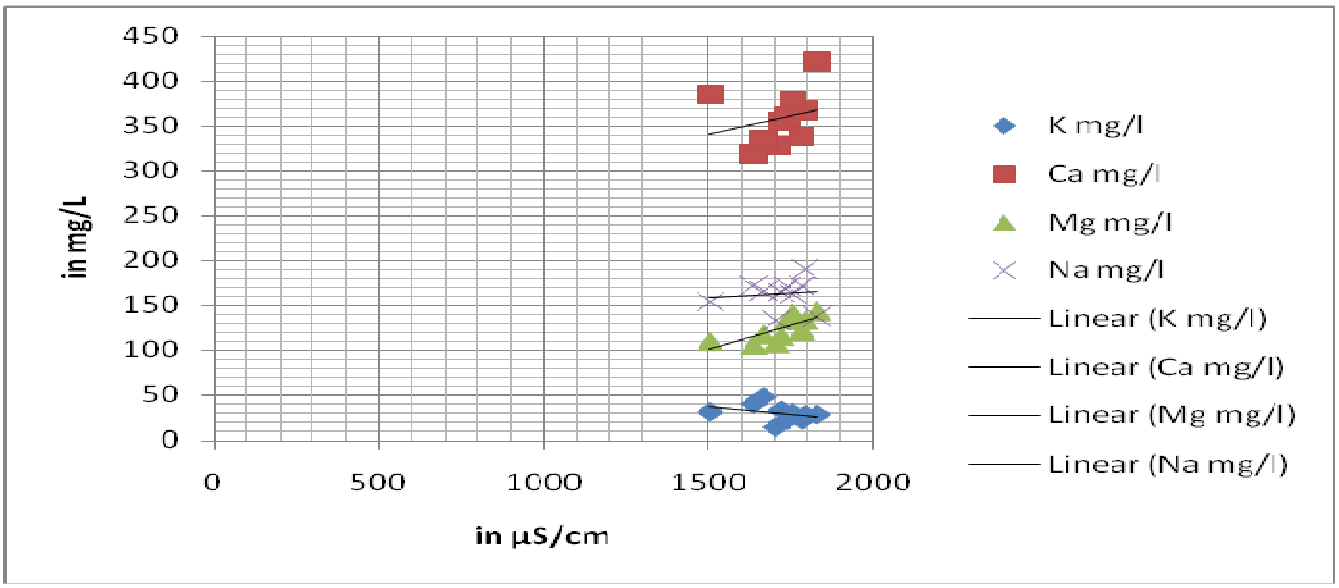


Figure 7: The Na, K, Mg, and Ca vs EC (Linearity trend)

4. Conclusion

A total of 120 questionnaires were filled out in the targeted areas in both the Governorates of Bethlehem and Jerusalem for farmers. The questionnaires revealed that the vast majority of the respondents are permanent residents and do not leave their dwellings at all. The majority of the respondents replied that there is a shortage of water in the area and they suffer as a result in their households. Most of the respondents cultivate a total land area between 1 and 5 dunums, while it was reported that less than 1 dunum is irrigated. Analysis shows that the most common water source used for irrigation is the public network, noting that a considerable portion use wastewater whether treated or not. The average fee paid for water for agricultural purposes is 4 NIS/m^3 ranging from 0, which is only a minority to 5 while an average farmer uses an annual quantity of 136 m^3/dunum. The water is used to irrigate a variety of crop types, the percentage of respondents that cultivate each particular crop type. The crops are solely used for personal consumption. The respondents thought was the main objective behind the treatment of wastewater, results show that the opinions were diverse. Health and environmental risks were anticipated to be the two major concerns in both cases. About 43% of the respondents reuse the domestic water used in their households for cleaning purposes reuse it in irrigating gardens.

The majority of the respondents are willing to use restricted water for irrigation but were reluctant on using unrestricted water for the same purpose. It is worthy to note that more than half of the respondents are willing to pay for treated wastewater, while the majority believe that the fee should be less than that of fresh water for both restricted and unrestricted water. The average amount thought to be a suitable fee for treated water used in irrigation is 1 NIS/m^3 while the highest price the respondents were willing to pay for water used in irrigation averaged to an amount of 1.5 NIS/m^3. About 79% of the respondents replied that they were not willing to use unrestricted wastewater in case there is no fresh water. About two-thirds of the respondents know of the existence of measures and standards that restrict the reuse of wastewater for irrigation. The vast majority of the respondents believe in the importance of involving farmers in decision making and the importance of water and environmental awareness. About half of the respondents say that group meetings with specialists are the most efficient awareness mechanisms followed by visits conducted by agricultural guides. In addition, many have never been targeted by an environmental awareness campaign.

A total of 117 questionnaires were filled out in the targeted areas of Wadi Nar Governorate of Bethlehem for consumers. According to the respondents the average water consumption of the families is estimated to be 22 m^3/month with an average monthly water bill of about 134 NIS. More than half of the respondents suffer from the shortage of water supplied through the public network as a result many of them own rainwater harvesting cisterns, with an average capacity of 50 m^3.

Only a minor portion of the sample purchase water from water tankers as a supplementary source with annual costs ranging between 100 and 1000 NIS/year at an average of 433. About 66% of the sample do not pay anything for disposing their wastewater while the average cost for those who do is about 473 NIS/year ranging from 50 to 1600. Almost half of the respondents thought that the main objective of treating wastewater is to avoid health risks and their anticipation on the risks associated with using untreated and treated wastewater respectively for irrigation. It can be concluded that damage to the groundwater and the economy are not major concerns in both cases with health risks are thought to be a threat to many whether treated or not. Logically, the majority of the respondents replied that they are interested in knowing the source of water used for irrigation. Respondents believe that the main factor that influences the consumption of products irrigated with treated wastewater is the fear from health risks. More than half of the respondents do not reuse domestic water used for cleaning in irrigating their gardens. The reasons behind the respondents' hesitation for consuming products irrigated by treated wastewater mainly being that the farmers will not use the right quality of water. More than half of the respondents refuse to pay for fruits and vegetables irrigated with treated wastewater. About 60% of the respondents know of the existence of measures and standards restricting the reuse of treated wastewater. Slightly more than 60% of the sample use water saving techniques. A good portion of the sample believes in the importance of involving consumers in decision making, while the majority believe in the great importance of environmental and water awareness. The distribution of responses regarding the awareness techniques thought to be most useful, it is worthy to note that none of the respondents agreed that radio programs would be efficient.

The average of the BOD and COD in sampled wastewater is 185 and 320.6 mg/L respectively which reflect the dangerous impact of using this wastewater for irrigation. The average of EC is 1712 µS/cm with a max of 1820 µS/cm. The average of the Dissolved solids is 843 mg/L with a range between 905 and 745 mg/L. The Total suspended solids ranges between 376 and 308 mg/L with an average of 350.4 mg/L. These amounts reflects there harmful effect of their use in irrigation. The average of salinity of the analyzed samples in percent is 0.86 %, this reflects the large amount of salts that are containing in the Wadi Nar wastewater. The average concentrations of Ca, Mg, K and Na are 358.5, 123.4, 29.6 and 162.5 mg/L respectivley, while the average amounts of NH3, Total Nitrogen (TN) and PO4 are 23, 28.5 and 11 mg/L respectivley. The regualtion of water quality for irrigation is of international importance because agricultural products grown with contamionated water may cause health effects at both the local and international levels (Beuchat, 1998). The EC, TDS and TSS amounts of wadi Nar catchmnet is considered to be of moderate restriction of its use according to WHO stanadard (WHO, 2006). The most reliable index of the sodium hazard of irrigation is the sodium adsorption ratio (SAR) (Pescod, 1992). The SAR is defined by formula: $SAR = Na / ((Ca+Mg)/2)^{0.5}$. The average of SAR in the nalyzed samples is 19.4, which means of high sodium and may produce harmful levels of exchangable sodium in most soils. According to that the irrigation of wastewater may cause harmful effect to the consumers of the plants and crops when it is used for agriculture. This results matches with the result of both the analyzed questionnaires of farmers and consumers.

References

Beuchat, (1998). Food safety Issues, Surface decontamination of fruits and vegetables eaten taw: a review. *Food Safety unit, WHO, Geneva, p42*.

Environmental Quality Authority EQA, (2009). Wastewater data, unpublished, Ramallah, West Bank.

Pescod, (1992). Wastewater treatment and use in agriculture., *FAO irrigation and drainage paper 47, p26. Food and agricture organization, Rome, Italy*.

SPSS Inc., (1999). *SPSS Ver.10 for windows – Statistical package for the Social sciences. Chicago*, USA.

WHO, (2006). A compendium of standars for wastewater reuse in the eastern mediterranean region. Regional office for the eastern mediterranean and regional center for environemental health.