SAFE REUSE OF TREATED WASTE WATER IN AGRICULTURE

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MENAWARA

NON-CONVENTIONAL WATER
RE-USE IN AGRICULTURE
IN MEDITERRANEAN COUNTRIES

1. Why should we reuse treated wastewater in the agricultural sector?

Households, companies, industries generate wastewater that should be treated or reused before it is returned to the environment. If we do not treat it, wastewater:

- will pollute our clean water resources, both our surface and groundwater, and our soils;
- will create a breeding place for microbes, insects and rodents posing serious human health threats;
- will negatively impact agricultural production including polluting agricultural products;
- Will lead to soil degradation impacting the soil quality, productivity and biodiversity.

Moreover, the reuse of treated wastewater (TWW) offers an important alternative source to release pressure on the freshwater resources and can address the issue and crisis of water scarcity in Palestine. Especially TWW reuse in agriculture presents for the occupied Palestinian territory a valuable resource as the Palestinian agricultural sector is responsible for the consumption of 60 to 70% of freshwater resources. Other human health, environmental and economic benefits of TWW reuse are:

- reduces the costs of groundwater extraction;
- reduces the use of (artificial) fertilizers;
- reduces environmental pollution of water bodies and soils caused by disposal of (untreated) water;
- potentially reduces social tensions between neighbouring communities;
- forms an incentive for investments in environmental pollution control and prevention.

Ultimately reuse of TWW will contribute to the transition towards a more circular economy in Palestine.

2. What is treated wastewater?

Treated waste water is waste water that has been clarified from some or all its suspended, sediment and dissolved materials by natural or mechanical, chemical or biological methods, whether individually or collectively, which do not exceed the maximum levels listed in the Palestinian Technical Standards (PSI, TR-34, 2012). The major aim of wastewater treatment is to remove as much of the suspended solids and of other pollutants as possible before the remaining water, called effluent, is discharged back to the environment. There are many technologies to treat wastewater, depending on the characteristics of wastewater and the required effluent quality.

3. Wastewater treatment plant of Beit Dajan

In Beit Dajan, located in Area B with a population of around 5,000 people and a growth rate of 1,8%, 70% of the households are connected to the municipal sewage system. This domestic wastewater is conveyed to the WWTP located at the entrance of the village, between Beit Dajan and Beit Furik as shown in Figure 1.

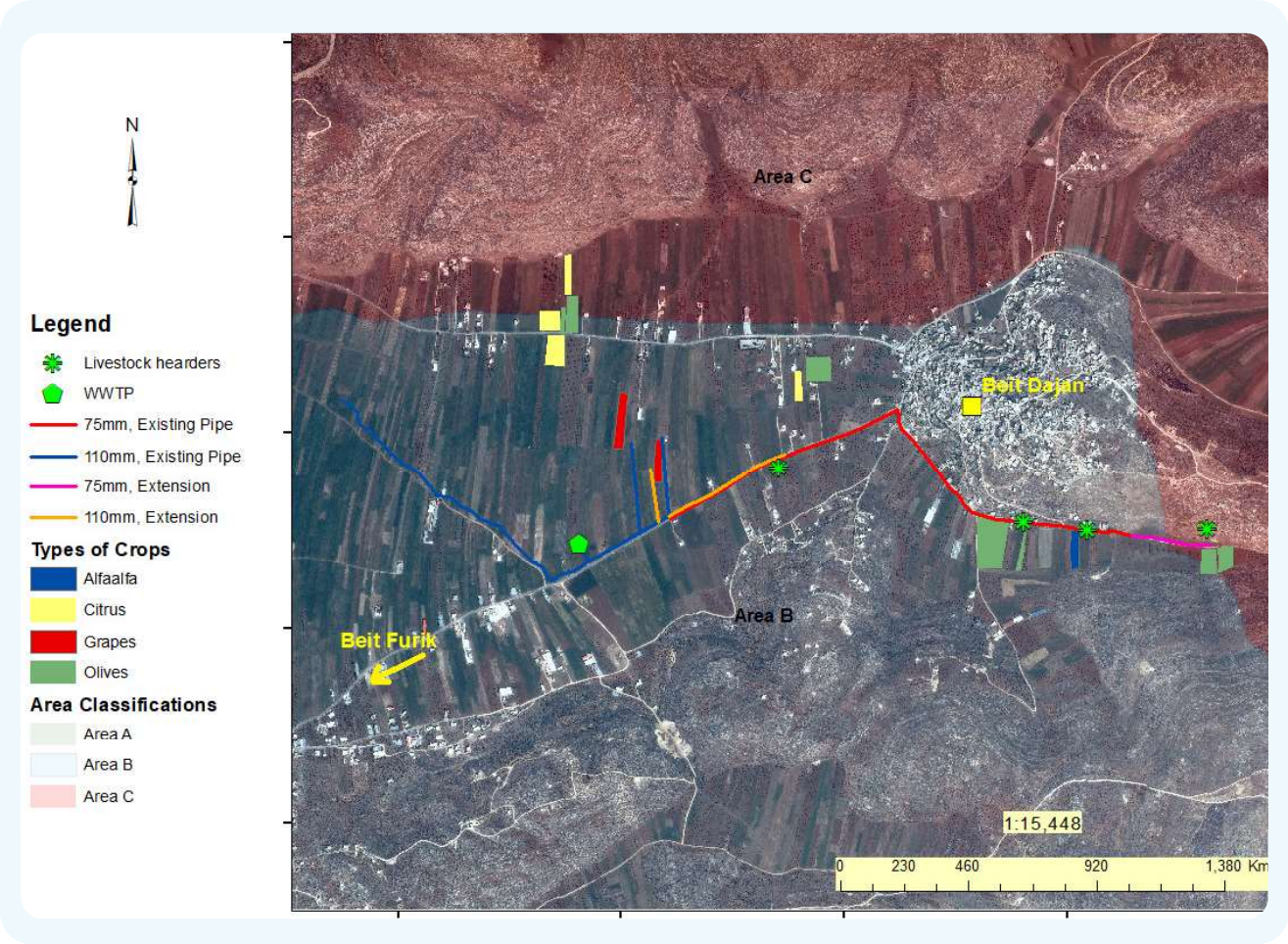

Figure 1 Location of Beit Dajan, its WWTP, the main pipelines of the irrigation network and the plots irrigated with TWW..

The image below (Figure 2) shows the wastewater treatment process of the WWTP of Beit Dajan from the point of entry to the pumping to the irrigation network namely:

1. After passing through a screen to remove the coarse solids
2. the water is collected in a tank or collection unit
3. the wastewater is pumped to the new 'pre-treatment' unit installed during the latest intervention of WeWorld-GVC under the MENAWARA project where fats and grease and finer grit (including sand materials) are removed.
4. Then, the water goes to the aeration tank where wastewater is mixed with oxygen and sludge full of microbes which will degrade pollutants in the wastewater.
5. From there, the water goes into a 'clarifier' where water is separated from the sludge and
6. then the water goes into an equalization tank from where the water is pumped
7. to the newly installed sand filters to remove the remaining suspended solids.
8. Finally, after passing through the chlorination unit where pathogens including bacteria, viruses and parasites are deactivated,
9. the water is collected in an effluent tank with a 500,000 L storage capacity.
10. From there it is ready to be distributed to the irrigation network.

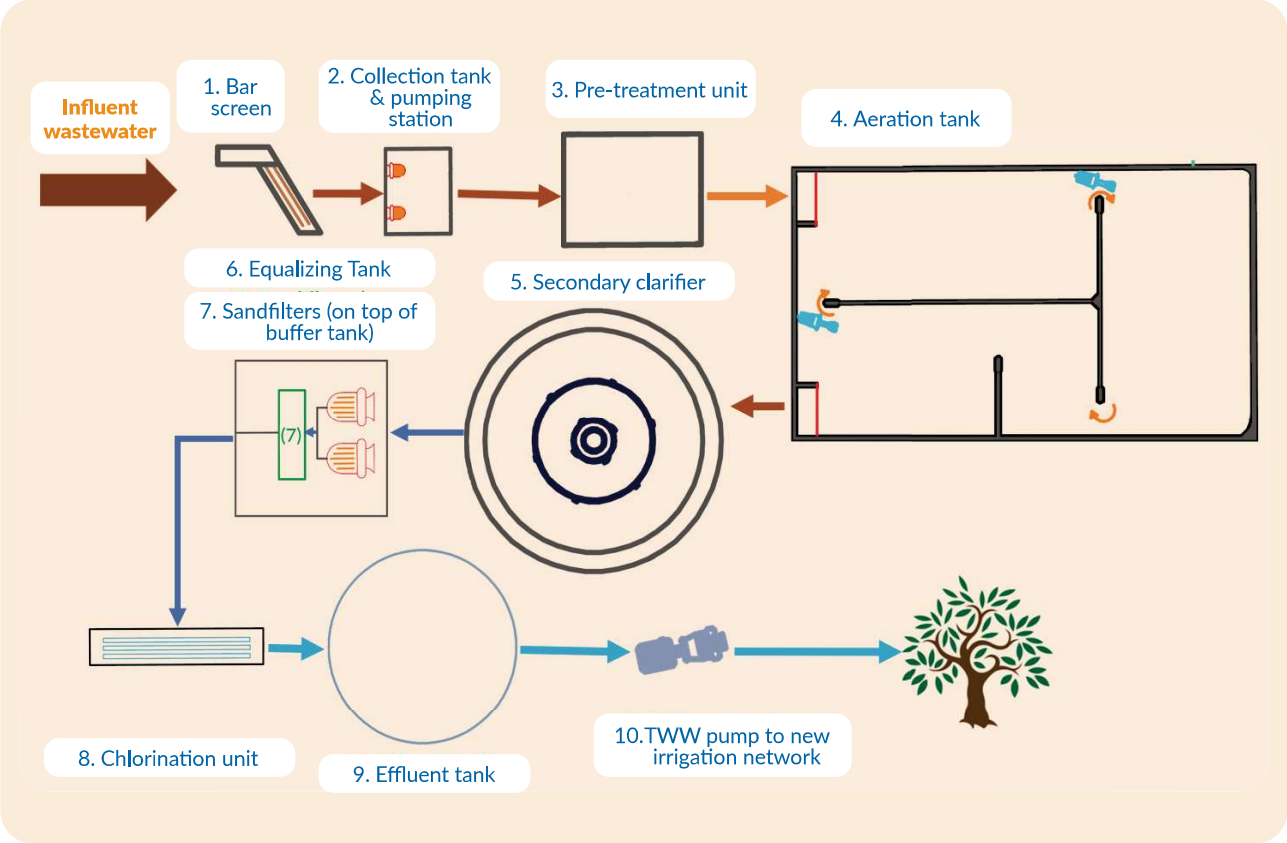

Figure 2 Schematic representation of WWTP of Beit Dajan. Green coloured items indicate rehabilitated or newly constructed assets by the MENAWARA intervention.

Wastewater contains excess nutrients, (un)dissolved solids, heavy metals, pesticides, and pathogens and hence TWW must comply with minimum standards in order to be reused. The water quality coming out from the Beit Dajan WWTP should reach minimally grade C quality according to the Palestine standards set by Palestinian National Authority for Treated Wastewater, but possibly grade B can be reached. The table below (Table 1) shows these standards for the most important parameters.

Table 1 Palestinian technical standards for treated water reuse of Class B and C for general parameters including microbiology.

Parameter (mg/L, if not specified)	Class B Good quality	Class C Medium quality
General TWW parameters (chemical and physical)		
Biological Oxygen Demand (BOD)	20	40
Chemical Oxygen Demand (COD)	50	100
Total Suspended Solid (TSS)	30	50
Total Dissolved Solids (TDS)	1500	1500
Dissolved Oxygen (DO)	>1	>1
pH	6-9	6-9
Fat, Oil, & Grease (FOG)	5	5
Nitrate (NO3-N)	20	30
Ammonium (NH4-N)	5	10
Total Nitrogen (TN-N)	30	45
Phosphate (PO4-P)	30	30
Microbiological parameters (indicators for faecal contamination)		
Feacal colonies (Colony/100 ml)	<1000	
Escherichia Coli (Colony/100 ml)	<1000	
Nematodes (Eggs/l)	≤1	

Water from the treatment plant of Beit Dajan should only be used to irrigate trees, fodder or field crops but not vegetable crops. Using this water for other uses can be harmful to your health, that of others and the environment.

4. Irrigation with TWW from Beit Dajan WWTP

Considering the quality of the TWW coming from the Beit Dajan WWTP, not all crop species can be irrigated with this water. According to the Ministry of Agriculture (MoA), vegetables are not allowed to be irrigated and other crop types must be approved by the MoA.Table 2 below shows this list of crops that can be irrigated with TWW including their yearly water requirement. In Beit Dajan TWW is used to irrigate the already established olives, grapes and citrus plots with drip irrigation and a newly introduced fodder (Alfalfa sp.) plot with subsurface irrigation. If farmers would like to irrigate other crops than these from this list, it should be coordinated with the MoA.

Table 2 Overview of crops that can be irrigated with Treated Wastewater according to the Palestinian Ministry of Agriculture and their Yearly Crop Water Requirement.

Crop	Yearly Crop Water Requirement (mm)
Olives	505
Almonds	1251
Alfalfa subsurface	1333
Alfalfa sprinkler	1600
Citrus	750
Grape	1027

The MoA will check on regular basis the quality of TWW and can conduct site inspections to observe and request the removal of any unauthorized planted crops that are not permitted to be watered by TWW listed under PSI, TR-34, 2012.

Irrigation frequency and interval should be properly scheduled when using TWW. After consulting and collaborating with MoA (Nablus directorate) the MoA advised about the water requirement for each type of crops and. The Italian research institute CIHEAM Bari in collaboration with WW-GVC modelled and calculated for every plot the amount of TWW needed using meteorological data, soil characteristics, crop type and number of plants. Based on these results and the WWTP effluent quality, the irrigation network was designed, water allocation to each farmer determined and proper irrigation management practices recommended. This is shown in Table 3.

A Water User Association (WUA) was created to coordinate and manage the TWW irrigation network between the farmers. Monthly meetings are organized between the farmers and the village council (VC) of Beit Dajan to discuss concerns regarding water quantity, water quality and tariffing. A recommendation from the meetings were to keep the water free of charge for the farmers. Indeed, farmers should do not pay for the water itself according to the 'polluter-pays' principle but should contribute to the cost of the operation and maintenance of the irrigation network. The farmers received multiple training sessions in order to understand the system and be enabled to manage the irrigation network (including on water requirement and scheduling of irrigation & network maintenance).

Table 3 Water requirement and water allocated per plot that will be irrigated by the TWW from WWTP of Beit Dajan.

Plot number	Crop species	Area of land plot (m^2)	Yearly water requirement need[1] (mm/m^2)	Total irrigation water allocated (mm)
1	Grape	4,087	750	3065.25
2	Grape	6,082	750	4561.5
3	Lemon	7,079	750	5309.25
4	Lemon	4,979	750	3734.25
5	Olives	1,493	300	447.9
6	Olives	5,467	300	1640.1
7	Lemon	3,539	300	1061.7
8	Alfalfa	3,698	1100	4067.8
9	Lemon	3,009	750	2256.75
10	Olives	7,674	300	2302.2
11	Olives	18,006	300	5401.8
12	Olives	1,988	300	596.4
13	Olives	5,188	300	1556.4
14	Olives	4,667	300	1400.1
Total		**76,956**		**37,401.4**

5. How to safely manage TWW?

It is important to be aware that treated wastewater in agricultural irrigation, if not managed properly, has the potential to harm your health, the public health, the environment, plant production, crop quality and the soil conditions including soil salinization.

1 Calculated considering the soil characteristics, meteorological data and the crop needs. Calculation based on data from MoA

Below some of the most important do's and don'ts when working with TWW are listed:

To do	NOT to do
✓ Have appropriate signage and notifications of taps, pipelines (purple) that the water is non-potable; ✓ Have appropriate signage of agricultural areas that are irrigated with TWW; ✓ Have appropriate separation of potable and non-potable water systems; ✓ Have a proper drainage system so that TWW does not accumulate; ✓ Irrigate as much as possible at the root of trees and avoid the creation of droplets and mist; ✓ Use appropriate irrigation run time and amount of water applied; ✓ Consider nutrients present in the TWW when applying fertilizers; ✓ Wear appropriate clothing and working outfit (long sleeves and pants and gloves); ✓ Have good personal hygiene, including washing hands regularly; ✓ Monitor soil conditions regularly.	× Use TWW for drinking or washing food; × Use TWW to irrigate crops that are not approved by the Ministry of Agriculture for this water quality; × Use TWW for washing your hands or any part of the body; × Let TWW accumulate in ponds; × Use TWW on non-approved site; × Remove signage or notifications for non-potable water.

So, there are health risks related to the use of TWW, but if used properly and following these general good practices, these risks can be mitigated and it can be perfectly safe to use TWW to irrigate your trees.

6. Maintenance of Irrigation network

There are two type of irrigation systems installed in the TWW irrigation network of Beit Dajan, namely drip irrigation for the plots with trees and subsurface irrigation for the fodder plots. For the subsurface irrigation the major components are the Polyethylene (PE) pipes. The major components of the drip irrigation system include the main pipeline, branched pipes, filters, dripper lines, and emitters. The maintenance of each item will be discussed below.

A) Follow-up and Maintenance of Polyethylene Pipes (main and branched pipes)

For the closed purple coloured Polyethylene (PE) pipes system, the main maintenance activities are:

- Monitoring daily the main pump pressure. This will be done by the operator at the

WWTP, to ensure that the pressurized water flows inside the main pipeline under sufficient pressure and continuously to prevent stagnation of minor solids inside the main pipeline, branched pipes, and dripper lines.

- Daily monitoring by the Village Council of the internal pressure of the water network.
- Monthly following up by the Village Council on the points most vulnerable to leakage, namely the:
    - Mechanical connection points
    - Pipes fitting points
    - Welding points

If you detect a leak at the mechanical connection points, the connections should be replaced ensuring that the new connections are reinstalled correctly. If you detect a leak in one of the main pipes, the leakage point should be cut off and reconnected with new mechanical connections or a new welding.

B) Follow-up and maintenance of Water Dripper lines by farmers

For the drip lines:

- Manually clean on weekly or minimally on monthly basis the dripper lines to protect them from blockage by removing the lines and wash them using fresh water from domestic source or tanker.
- Observe on monthly basis the connection of the dripper lines with:
    - pipe saddle;
    - the starting point of the pipe between the saddle and the drip lines.
- And check on monthly basis:
    - Irrigation pipe flow (more or less than required);
    - Irrigation holes blockage.

If there are any leaks, the connections should be reinstalled or damaged part should be replaced.

C) Maintenance for emitters (drippers) by farmers:

For the emitters:

- At the start of the irrigation season, check the damage or the blockage of the emitters.
- During the irrigation season :
    - Follow up the pressure gauge reading monthly at the entrance of each zone to ensure that the emitters and drip lines will not be subjected to the high pressure, but sufficient pressure.
    - Manually clean the emitters on weekly or minimally on monthly basis to protect them from blockage. By removing them and washing them using the fresh water together with the drip lines.
    - Check for leakages at least monthly.
    - Inspect at least once for any blockage or damaged drippers.
- At the end of irrigation season: inspect the drain, pressure and compliance with the manufacturer's specifications and for any blockage or damaged drippers.

There are several factors that can lead to blockage of emitters (Box 1). Preventing is easier, cheaper and better than remediate for example by the installing and maintaining filters before the drip lines. Yet, not all blockages can be prevented and remediation of some types of blockages is possible through:

- Calcium carbonate (white deposit): Add acidic solution to increase the pH to the water and increase the water pressure for 30 to 60 minutes IF NOT all points are blocked. If all points are blocked, the emitters must be removed and washed manually.
- Iron deposition (rusty deposit), calcium sulfate and bacterial growth (and other sticky substances): adding a chlorine solution to the water following MoA's advice. Be careful when using chlorine and follow product's safety guidelines.
- Algae: by adding copper sulfate in bags that float on the surface or scattering it on the surface of the water tank.

Box 1 Factors that lead to blockage of the emitters (drippers)..

Physical agents	Chemical agents (Precipitation)
- Organic particles, plants or algae - Inorganic, such as sand, clay, etc.	- Calcium carbonate - Calcium sulfate - Heavy metals - Phosphate fertilizers - Water Ammonia solution

D) Maintenance of filters:

Filters are installed to protect the dripper lines and emitters from clogging. There are different types (sand, mesh and disk filters) and sizes of filters and each filter has a limited capacity for holding. The filters installed at the irrigation network of in Beit Dajan are disk filters. To keep the installed filters working with high efficiency, they should be cleaned frequently, minimally one a month, from the accumulated suspended solids and washed and rinsed with freshwater.

To summarize, an irrigation network asks for regular inspection and maintenance from the farmers. By regular surveillance and timely intervention, the impacts and costs of maintenance and replacement of components of the irrigation network can be minimized.

7. Responsibilities and monitoring

Important for the proper functioning and the sustainability of the irrigation scheme is to have the responsibilities of all the stakeholders involved clear to all involved parties as defined in the Memorandum of Understanding between Beit Dajan VC and the WUA. The responsibilities of the most important stakeholders in the operation and functioning of the TWW irrigation network are shown below (Tabel 4). Other important stakeholders not mentioned in the table are the Environmental Quality Authority and the Ministry of Local Governments.

Table 4 Most important stakeholders in the operation of the irrigation network of Beit Dajan and their respective responsibilities.

Stakeholder	Responsibility
Water User Association (WUA)	▯ Managing the distribution of TWW for the farmers who have the permission from the MoA ▯ Collecting the fees from farmers ▯ Operation and maintenance of irrigation scheme ▯ Have regular meetings to monitor and evaluate the sustainability of the irrigation network, identify and discuss issues: · Internally with the WUA · monthly meeting with VC ▯ Regularly revise irrigation method including the water quantity and distribution ▯ Define and monitor the number of trees that can be irrigated with TWW
Individual farmer	▯ Comply with regulations and the terms of license
Village Council of Beit Dajan (VC)	▯ Operation of WWTP ▯ Maintenance of WWTP ▯ Have monthly meeting with the WUA ▯ Monitor the water quality coming out of WWTP ▯ Definition of schedule and collection of tariffs from WUA ▯ Request training for operators to the PWA ▯ Information sharing with farmers and local population on TWW
Ministry of Agriculture (MoA)	▯ Regular inspection of produce ▯ Licensing of the WUA to reuse TWW for food production
Palestinian Water Authority (PWA)	▯ Training of operators of the WWTP ▯ Develop together with the VC a water tariff system acceptable by both farmers and VC

The table (Tabel 5) below shows the frequency of monitoring and checks needed and provided in the MoU (see "monitoring protocol") and the responsible actor for each type of monitoring.

Table 5 Type, frequency and responsible actor in the monitoring for the operationality and compliance of the WWTP and irrigation network of Beit Dajan.

Type of monitoring	Frequency	Responsible
Operationality of the WWTP	Every 3 months and upon need	Beit Dajan VC
Operationality of water irrigation scheme	Every 3 months and upon need	WUA
Inspection of produce	Every 3 months	MoA
Soil Analysis	Every 3 months	MoA
Water analysis	Every 6 months	Beit Dajan VC PWA and MoA

8. Palestinian regulations relevant for reuse of TWW in agriculture

Considering the need of water reuse in Palestine but also the possible health and environmental risks it is important to have laws around water reuse. Though there is no specific law yet for TWW in agriculture (nor domestic) in Palestine, there are some laws and regulations that are relevant in the context of TWW use in agriculture including:

- Law 7/1999: The Palestinian Environmental law, 1999.
- Law 3/2002: The Palestinian Water Law, 2002.
- Law 2/2003 : Agricultural Law, 2003.
- Agreements with Israel, particularly the Memorandum of Understanding (MoU) of December 2003.
- PS 742/2003: The Palestinian Treated Wastewater Standards, 2003.
- MoA Instructions/2011: The Ministry of Agriculture instructions for treated wastewater reuse in agriculture, 2011.
- TR 34/2012: Technical Regulations for the reuse treated wastewater in agricultural irrigation (PSI, TR-34, 2012).
- The Palestinian Water Law 2014.

A copy of these relevant regulations and standards are available at the VC and WUA and can be consulted by all farmers.

9. Rehabilitation of the WWTP and network: lessons learnt and take-aways

The rehabilitation of the existing WWTP improved the TWW significantly as the WWTP at the start of the project was almost completely dysfunctional and in dire need of maintenance. Next to general maintenance, the installation of a new more effective pre-treatment unit and the sand filters where to major interventions that contributed to improved quality of the effluent next to the optimization of the operation of the aeration tank. A lessons learnt from the WWTP rehabilitation is that monitoring the plant on regular basis the plant is vital to ensure safe effluent for reuse and timely action in case an operational issue arise.

Maybe more important than the technical aspects when working with TWW, are the social aspects. Working on changing more negative perceptions and increasing awareness of TWW reuse within the community including the farmers is important. Trainings and exchanging experience with farmers from other places and countries, help in changing this perception as increasing their capacity and knowledge. Of course, the safety aspects shoud also be stressed during these interactions. For both farmers and operators, practical and regular capacity building sessions is important to ensure safe reuse of TWW. Moreover, transfer of knowledge amongst peers should be encouraged.

Finally, for the sustainability of the project and the WUA and TWW management system put in place, it is important the there is good and regular communication and discussion between the stakeholders so that all stakeholders remain and feel involved in the TWW reuse in Beit Dajan

10. Advantages and lessons

The general public and the farmers in Beit Dajan have gained advantages in both domestic and agriculture levels due to proper functionality of WWTP and the farmers are able to reuse the treated water, whom also has encouraged to invest in agriculture and the livelihood activities, additionally the benefits on environmental level as well, and the change of public perception about reuse.

Furthermore, the governance aspect that is adopted through the project, by forming TWW user association, which have an agreement with the village council for quality effluent and reuse of the TWW, is a key element to enable proper management of both the WWTP by the village council, and the irrigation systems by the User Association.

Nevertheless, through the implementation of MENAWARA project, there were lesson learned came out that are essential to the long run and sustainability of the infrastructure to remain always producing safe reuse, Local authorities should take measures to ensure knowledge transfer when key staff retires or relocates to ensure that knowledge on WWTP and TWW gained through years of experience is maintained and built upon, and also to put more efforts on awareness for the general public and demonstrate the benefits and safety of reusing the TWW.

11. Contact details

If you have any questions or concerns regarding the use of TWW in agriculture (including technical questions, regulations, and terms of license), you can contact any of the persons below.

Organization/Institution	Name	Role of contact	Contact
WeWorld-GVC	Qusay Abu Dawas	Agronomist	059-421-1375
Ministry of Agriculture	Reema Dallal	Water technical director (Nablus DoA)	059-420-1475
Palestinian Water Authority	Adel Yaseen	Planning general director	059-791-5850

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