WP3. ACTIONS TO INCREASE THE QUALITY OF NON CONVENTIONAL WATER USED IN AGRICULTURE

Output 3.5. Report on the efficiency of the implemented pre and post treatments and MAR systems

A 3.5.2 Evaluation of the efficiency of post treatment systems on non-conventional water. Beit Dajan WWTP, occupied Palestine.

Responsible partner: WE WORLD

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TABLE OF CONTENT

TABLE OF CONTENT 2

ABBREVIATIONS AND ACRONYMS 3

1. BACKGROUND 4

2. AREA OF INTERVENTION 6

3. STANDARD FOR WATER REUSE IN AGRICULTURE IN OCCUPIED PALESTINE 8

4. METHODOLOGY 10

5. ASSESSMENT OF WATER QUALITY 12

6. OPERATION AND MAINTENANCE 16

7. LESSONS LEARNED 17

8. CONCLUSION 18

ABBREVIATIONS AND ACRONYMS

Acronym	Description
BOD	Biological Oxygen Demand
CENTA	Fundación Pública Andaluza Centro de las Nuevas Tecnologías del Agua
CFU	Colony Forming Units
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
FOG	Fats, Oil and Grease
MAR	Managed Aquifer Recharge
MBAS	Methylene-blue Active Substances
MoA	Ministry of Agriculture
NCW	Non-Conventional Water
NTU	Nephelometric Turbidity Unit
O&M	Operation and Maintenance
SAR	Sodium Adsorption Ratio
SVI	Sludge Volume Index
TDS	Total Dissolved Solids
TNTC	Too Numerous To Count
TSS	Total Suspended Solids
TWW	Treated Wastewater
WP	Work Package
WWTP	Wastewater treatment plant

1. BACKGROUND

This technical report has been written in the context of the third Work Package (WP3) of the MENAWARA project on *Non-conventional Water Re-use in Agriculture in Mediterranean countries* and more specifically for **Output 3. 5 "Reports on the efficiency of the implemented pre and post treatments and MAR systems"** and **Activity 3.5.2 "Evaluation of the efficiency of post treatments systems on non-conventional water"** as described in infographic below (Figure 1).

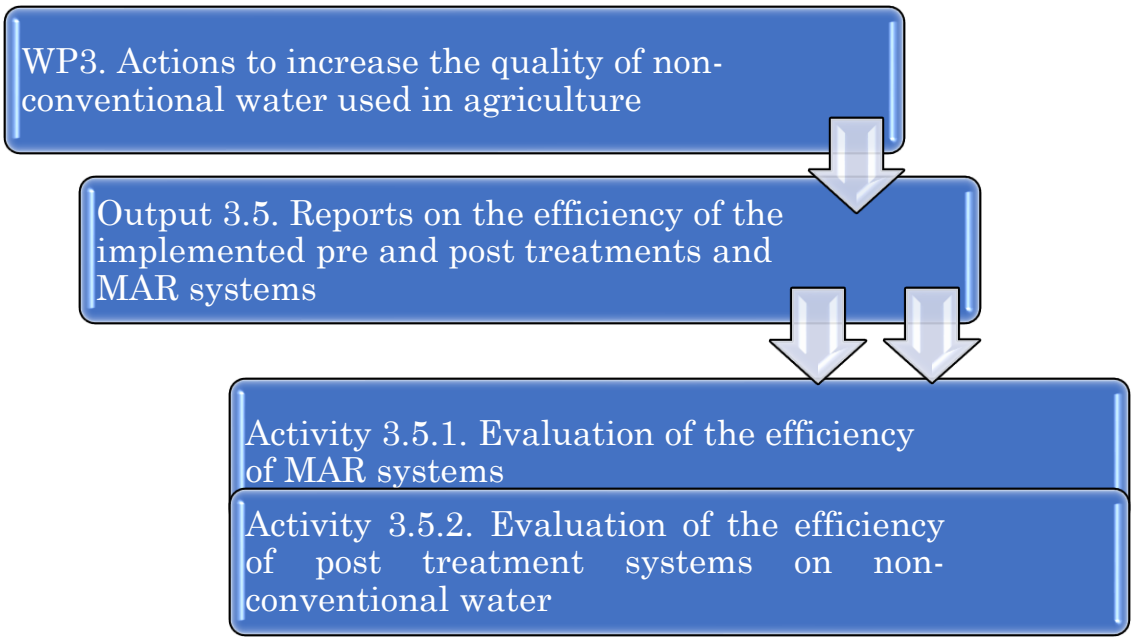

Figure 1. Infographic on the context of this technical report. MAR: Managed Aquifer Recharge.

More specifically the Output 3.5 is described as follows: "Technical reports on the assessment of the efficiency of the implemented treatments and MAR systems will be produced by all involved partners supervised by CENTA. They will include all monitoring data related to the quality of the inlet water and TWW coming out from the post-treatment systems, the recharge water used for the FIA systems and groundwater of the sandy aquifer in Arborea as well as the Operation and Maintenance (O&M) activities carried out and the lessons learned".

This document details the quality of both the non-conventional water (NCW) and treated wastewater (TWW) coming out from the post-treatment systems implemented at the Beit Dajan WWTP, occupied Palestine, the monitoring and evaluation through bulk analytics, including the quality parameters (Physico-chemical and microbiological) established in the respective National standards for the reuse of TWW in agricultural irrigation in Palestine (Palestinian Technical Standards for Reuse of Treated Wastewater in Agriculture[1]), the O&M activities carried out and the lessons learned over the period from January to August 2023, as part of Activity 3.5.2 "Evaluation of the efficiency of post treatment systems on non-conventional water".

The results of this report are complementary to Activity 3.1.1 "Field assessment of the efficiency of the WWTP and the quality of non-conventional water" under output 3.1 "Non-conventional water quality indicators", and the technical aspects of outputs 3.2 "Efficient infrastructures and technical reports", output 3.3. "Pre and post-treatments and MAR systems designs and output 3.4 "No. of pre and post-treatment and MAR systems realized".

The document is structured as follows: i) an introduction and general overview of the WWTP after the implementation of both the minor and major intervention (section 2); ii) the National quality standard for water reuse in agriculture in occupied Palestine and the physical-chemical and microbiological parameters followed for the assessment of the NCW and TWW coming out from the post-treatment systems implemented at the Beit Dajan's WWTP (section 3); iii) the methodology including material and methods (section IV); the water quality including discussion of results obtained (section V); v) O&M activities carried out in the post-treatments implemented (section 6); vi) lessons learned and recommendations of possible improvements for up-scaling at the rural/local level (section 7) and vii) some concluding remarks (section 8).

1 Technical specifications 34-2012 Treated Wastewater for Agriculture Irrigation, Palestinian National Authority of Palestine Standards Institution, 2012.

2. AREA OF INTERVENTION

Beit Dajan is a Palestinian village in the Nablus Governorate in the North Central West Bank as shown in Figure 2. The village's population is around 5000 people with 85% of households connected to the sewer network. The WWTP is located at the eastern edge of Beit Dajan village and has a daily wastewater production around 250-350 m3 /d. The treated wastewater (TWW) is used to irrigate surrounding agricultural lands, which are cultivated with olives, almonds, alfalfa, grapes and lemons.

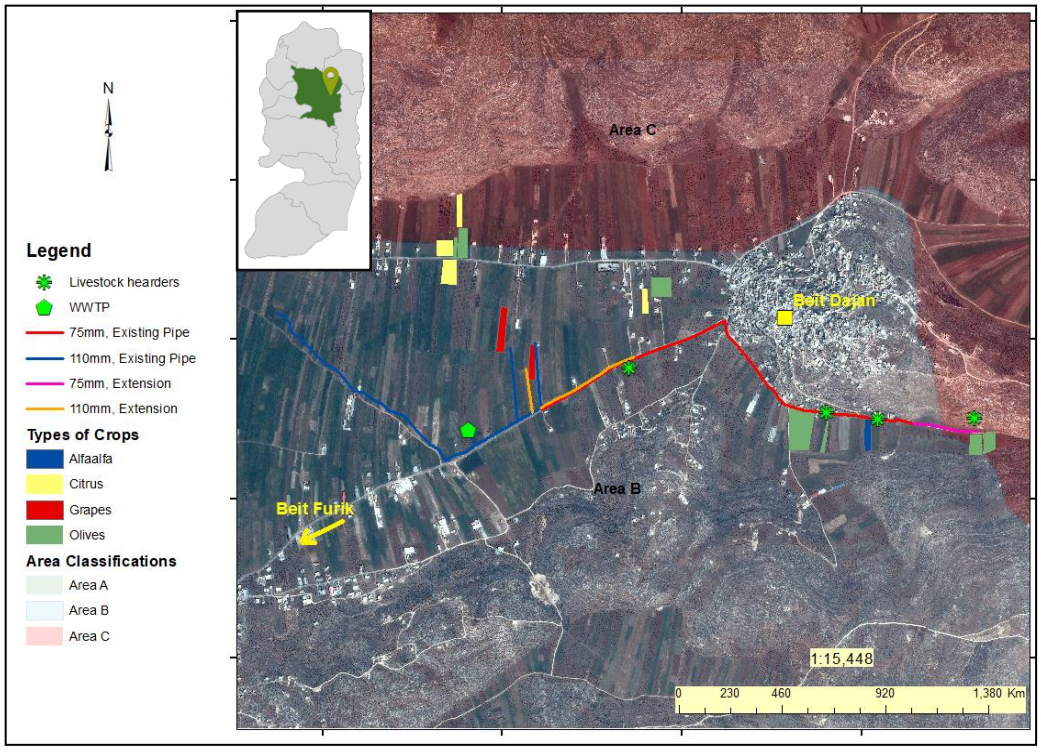

Figure 2. Map to illustrate location of Beit Dajan Village, its wastewater treatment plant (WWTP), the main pipelines of the installed irrigation network and the plots irrigated with treated wastewater (TWW).

The wastewater treatment process of the WWTP of Beit Dajan from the point of entry to the pumping to the irrigation network namely is shown in Figure 3 after the implementation of the minor and major intervention under MENAWARA. After passing through a screen to remove the coarse solids the water is collected in a tank or collection unit and then is pumped to a pre-treatment unit to remove the grit and sand (part of the Total Suspended Solids or TSS) and fats, oils and grease (FOG). Then, the water goes to the aeration tank, then to the secondary 'clarifier' and into an equalization tank in order to remove mainly the organic load, ammonium and phosphorus. From there the water is pumped to sand filters to mainly further reduce the

TSS load. Finally, after passing through the chlorination unit the water is collected in an effluent tank with a 500,000 L storage capacity. From there it is ready to be distributed to the irrigation network.

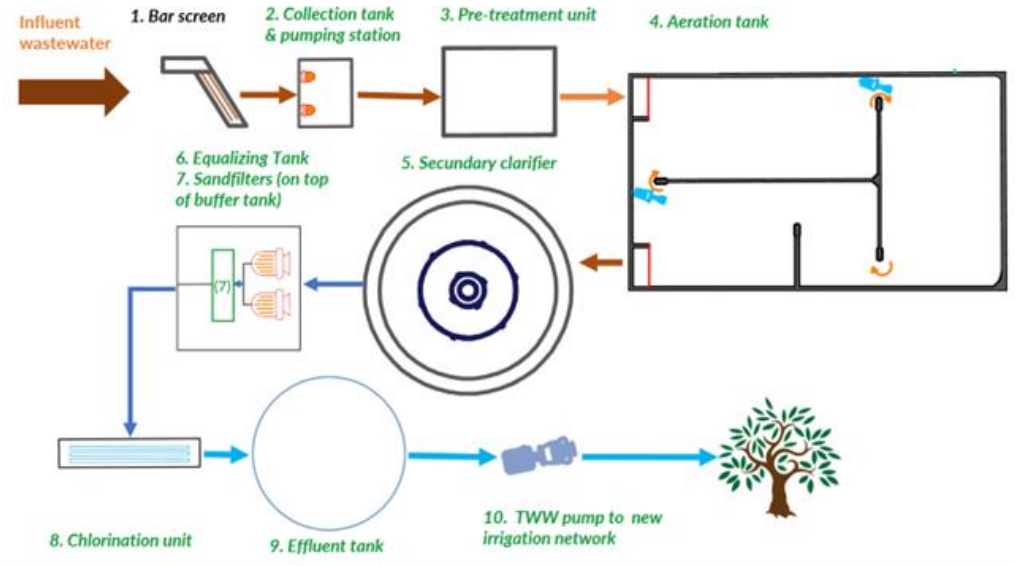

Figure 3. Schematic representation of WWTP of Beit Dajan. Green coloured items indicate rehabilitated or newly constructed assets by the MENAWARA minor and major intervention.

3. STANDARD FOR WATER REUSE IN AGRICULTURE IN OCCUPIED PALESTINE

The Palestinian National quality standards for water reuse in agriculture are shown in the Table 1 here below and in more details in Annex 1. There are four classes of treated wastewater (TWW) depending on the class and the set of barriers used, to irrigate certain crops.

Table 1. Palestinian National Standards for TWW in agriculture. MBAS: Methylene Blue active substances; SAR: Sodium Adsorption Ratio. CFU: Colony Forming Units

Parameter	Unit	TWW Category			
		High Quality (A)	Good Quality (B)	Medium Quality (C)	Low Quality (D)
Biological Oxygen Demand (BOD5)	mg/l	20	20	40	60
Total suspended Solid (TSS)	mg/l	30	30	50	90
Feacal Coliforms	CFU / 100 ml	200	1000	1000	1000
Nematodes	Eggs/l	<=1	<=1	<=1	<=1
E. coli	CFU / 100 ml	100	1000	1000	1000
Chemical Oxygen Demand (COD)	mg/l	50	50	100	150
Dissolved Oxygen (DO)	mg/l	>1	>1	>1	>1
Total Dissolved Solids (TDS)	mg/l	1200	1500	1500	1500
pH	-	6 -9	6 -9	6 -9	6 -9
Turbidity	NTU	5-10	5-10	5-10	5-10
Fat, Oil, & Grease (FOG)	mg/l	5	5	5	5
Total Nitrogen (T-N)	mg/l	30	30	45	60
Nitrate (NO3-N)	mg/l	20	20	30	40
Ammonium (NH4-N)	mg/l	5	5	5	5
Phosphate (PO4 –P)	mg/l	30	30	30	30
Max. Temperature	°C	35	35	35	35
Phenol	mg/l	0,002	0,002	0,002	0,002
MBAS	mg/l	15	15	15	15
Cl^-	mg/l	400	400	400	400
$SO4^{-2}$	mg/l	300	300	300	300
Na^+	mg/l	200	200	200	200
Mg^{2+}	mg/l	60	60	60	60

Ca^{2+}	mg/l	300	300	300	300
SAR	mg/l	5,83	5,83	5,83	5,83
Al	mg/l	5	5	5	5
As	mg/l	0,1	0,1	0,1	0,1
Cu	mg/l	0,2	0,2	0,2	0,2
Fe	mg/l	5	5	5	5
Mn	mg/l	0,2	0,2	0,2	0,2
Ni	mg/l	0,2	0,2	0,2	0,2
Pb	mg/l	0,2	0,2	0,2	0,2
Se	mg/l	0,02	0,02	0,02	0,02
Cd	mg/l	0,01	0,01	0,01	0,01
Zn	mg/l	2	2	2	2
CN	mg/l	0,05	0,05	0,05	0,05
Cr	mg/l	0,1	0,1	0,1	0,1
Hg	mg/l	0,001	0,001	0,001	0,001
Co	mg/l	0,05	0,05	0,05	0,05
B	mg/l	0,7	0,7	0,7	0,7

4. METHODOLOGY

This section details the location of water sampling points, sampling periods and periodicity, type of crop irrigated, irrigation method used and the analysed parameters and reference methods used.

WeWorld field engineer, supported by the selected laboratory at the An Najah university, took samples at several locations in the WWTP and at several times during the project implementation period to test the performance and efficiency of the minor and major interventions. **Table 2** gives an overview of the samples taken and parameters tested. Both grab and composite samples were taken (see Annex 2), composite samples were taken for the influent samples. The reference methods used for each of the analysis are specified in Annex 2.

Table 2. Overview of water quality sampling and testing performed for Beit Dajan WWTP.

DATE sampling	NUMBER of samples	STAGES sampled	PARAMETERS
13-May-2018	1	Effluent of WWTP	pH, COD, BOD, TDS, TSS
5-Jul-22	2	Raw inlet, pre-treatment unit outlet	TSS, FOG
28-Aug-22	3	Raw inlet, inside aeration tank, inlet secondary clarifier, outlet secondary clarifier	BOD,COD, SVI, T-P, T-N, TS, TSS, MLSS, pH
20-Sep-22	1	Sand filter inlet	BOD, TSS, Turbidity
31-Oct-22	2	Sand filter inlet, chlorination unit inlet	BOD, TSS, Turbidity
27-Nov-22	2	Sand filter inlet, chlorination unit inlet	TSS1,5; TSS8*
21/8/2023	4	Raw inlet, pre-treatment unit outlet, inside aeration tank, After chlorination unit	BOD,COD, SVI, T-P, FOG, PO4, T-N, TDS, TSS, Turbidity, NO3, NH4, chloride, EC, pH, *E. coli*, Nematodes, Feacal coliforms

** Total Suspended Solids with particle size respectively greater than 1,5 mm and 8 mm*

The crops, area and irrigation requirements for the plots that can be irrigated with the TWW from the WWTP of Beit Dajan are shown in

Table 3. The plots are also visualized in Figure 2.

Table 3. Crop species, area of land, water requirement and water allocated per plot irrigated by the TWW from WWTP of Beit Dajan.

Plot number	Crop species	Area of land plot (m^2)	Yearly water requirement need* (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

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

5. ASSESSMENT OF WATER QUALITY

This section includes the results and discussion on monitoring data related to the quality of inlet water and TWW coming out from the post-treatment systems and use for irrigation in the Beit Dajan's WWTP. Report data obtained from the laboratory are shown in Annex 2.

Both the major and minor interventions performed on the WWTP in Beit Dajan were necessary to obtain the overall functioning and performance of the WWTP.

The installation of the pre-treatment unit aiming at removing TSS and FOG and providing a more stable inflow quality was necessary for the aeration tank to work. When looking at the performance of the pre-treatment unit, it can be observed that the efficiency for the removal of TSS is lower than the maximum performance in the specifications (Table 4). However, this was expected as the load of TSS is 2 to 3 times higher than for the specified wastewater (TSS= 500pm). Regarding FOG, it is relatively close to the maximum performance of 70% and within expected performance. Overall, the performance of the compact unit is good and according to expectations. Moreover, the effluent coming from this unit is of stable quality, which is important for the performance of the aeration tank as can be seen in Table 4. Since the moment of its installation in 2022, no breakdown or significant operational problems have occurred.

Table 4. Water quality analysis results from the inlet and outlet of pre-treatment unit. TSS: Total Suspended Solids; FOG: Fat, oil and grease.

Parameter	Sampling date	Concentration (mg/l)		Removal efficiency
		Influent	Outlet	
TSS	5/7/2022	2100	1427	32%
	21/8/2023	953	629	34%
FOG	5/7/2022	282	122	57%
	21/8/2023	174	74	57%

The impact of the mixers on the performance on the aeration tank is connected to the installation of the pre-treatment unit. Overall, the aeration tank is performing well according to water analysis (Table 5) performed on samples collected from the aeration tank on several indicator parameters including Sludge Volume Index (SVI); Food to Micro-organism ratio, Dissolved Oxygen (DO). The results (increased SVI and BOD removal) indicate an improved operation of the aeration tank compared to last year

when the interventions in the pre-treatment and aeration tank were just finalized.

Table 5. Performance parameters of aeration tank based on water analyses done in November 2022 and August 2023.

Parameter	Unit	Nov '22	Aug '23	Explanation
SVI 30 (sludge settling ability)	mg/l	83,3	93,5	Ideally between 100-200 mg/l. The increase in SVI indicates a better aeration of the sludge. In addition, visual improvement of the sludge settling ability and quality was observed by the operators.
Food to Micro-organism ratio	-	0,6	0,51	This value indicates that the micro-organisms in the sludge are receiving sufficient organics to be able to process the incoming BOD.
BOD outlet	mg/l	78*	45*	The concentration of the BOD decreased compared to the first year showing likely the effect of improved operation of the aeration tank. *after sand filters
BOD removal efficiency	%	93	94	Though the increase in BOD removal efficiency might seem minor, it is a significant improvement in order to reach the quality standards of the Palestinian Authority.
Dissolved Oxygen	mg/l	When aerators where on the DO raised to 2,8-5,3 mg/l	2,2	The DO concentration is in expected range, showing that the mixers are putting sufficient air to enable the microorganisms to degrade the organic material.

The equalization tank ensures that the water quality after the secondary clarifier is more stable as well as the quantity. For the impact of the sand filters, they significantly contribute to further reducing the TSS content of the effluent treated wastewater (TWW) as can be seen in Table **6**. It is necessary to reach at least level C of the Palestinian classification for water reuse (see Table **1**).

Table 6. Removal efficiency of Total suspended Solids by the pressured sand filters.

Parameter	Sampling date	Treatment step	Value	Unit
TSS >1.5 µm	27/11/2022	Sand filters inlet	96	mg/l
		Chlorination unit inlet	18	mg/l
TSS Removal efficiency			81	%

After the minor and major intervention, there is an overall good performance of the WWTP as shown in **Table 7**. The removal efficiency of phosphate (PO_4^+) is low, but expected as the WWTP is not designed to remove P. The WWTP is designed to keep a certain level of P (30 mg/l) and N (20-50 mg/l) in the treated water as fertilizers for the farmers. The effluent water quality reaches satisfactory results and classification A is obtained for most parameters indicating an overall good performance of the WWTP as indicated in **Table 7**. Regarding the turbidity, the Palestinian standards are not met.

At the moment of the last monitoring round, the sand filters at the moment are not functional as the pressure group pumps is in maintenance, which the pressure pumps put the wastewater under sufficient pressure for the sand filters that is out of order now. then the sand filters will be on running, it is expected that the turbidity will reach the standards. Regarding COD and BOD, the classification of D has been obtained. Class C is expected to be obtained when the sand filters will be working again, Once these remedial actions are implemented, it is expected that TWW of Beit Dajan will obtain class C according to the Palestinian standards.

Table 7. Influent versus effluent quality based on water sampling and testing on 21/08/2023. BOD: Biological oxygen Demand; COD: CFU: Colony Forming Unit; DO: Dissolved Oxygen; FOG: Fat, oil and Grease NA: Not Applicable; NTU; Nephelometric Turbidity unit; TDS: Total Dissolved Solids; TSS: Total Suspended Solids; TNTC: Too Numerous to Count.

Parameter	Influent value	Effluent value	Unit	Removal Efficiency	Effluent TWW classification
pH	7.22	6.98	-	NA	A-D
Temperature	27	27	°C	NA	A-D
DO	-	2,3	mg/l	NA	A-D
BOD	730	45	mg/l	94%	D

COD	1327	105	mg/l	92%	D
Phosphate PO_4^+	32	26	mg/l	19%	A-D
Nitrate NO_3^-	0	16	mg/l	NA	A-D
NH_4^+	176.7	4.8	mg/l	97%	A-D
Total-N	188	23	mg/l	88%	A-B
TSS	953	21	mg/l	98%	A
TDS	1057	1096	mg/l	NA	A
Cl^-	-	222	mg/l	NA	A-D
Turbidity	128	26	NTU	80%	No classification
FOG	282	<5	mg/l	>98%	A-D
E. coli	TNTC	15	CFU/ 100 ml	>99%	A
Feacal coliforms	TNTC	30	CFU/ 100 ml	>99%	A
Nematodes	-	N.D/ 100ml*	Eggs/l	N.D/ 100ml*	A-D

6. OPERATION AND MAINTENANCE

This Section details the O&M activities carried out in the post-treatments implemented.

An Operation and maintenance O&M activity was held on 24th of November 2022, during the training of all the operators on the pre-treatment unit of Beit Dajan Municipality. The topics of this training session included as follows:

- Definition of the mechanical parts of the pre-treatment unit;
- Operation of the pre-treatment unit;
- Operation of the flushing system
- Potential operational errors and technical problems of the unit.

Also the operators were trained on the operation and maintenance of the sand filters (see **Figure 4**). The topics covered were as follows:

- Definition of the mechanical parts of sand filters and the pressure pumps;
- Understanding the electrical panel of the all system;
- Operation of the pumps and sand filters in auto-mode;
- Operation of the backwash system in three different modes: I) pressure mode II) timing mode III) manual mode;
- Potential operational and technical impacting performance of sand filters;

Figure 4. Training on operation and maintenance of the 2 installed pressured sand filters.

The training notes and attendance sheet of these trainings can be found in Annex 3. WeWorld's field engineers has coached the operators during constant field visits including training on the operation and optimization of the aeration tank.

7. LESSONS LEARNED

The lessons learned and recommendations for up-scaling the post-treatments implemented at the rural/local level from the rehabilitation of the WWTP of Beit Dajan are as follows:

- TWW is a needed resource in Beit Dajan:
- Engagement and cooperation of all stakeholders including local authorities, operators, farmers and contractors are crucial for the sustainability of the WWTP;
- Foreseeing adequate sampling points at the WWTP is important;
- Regular water quality monitoring of WWTP should be performed;
- Sufficient training of operators and farmers on operation and maintenance and safety aspects of respectively the WWTP and the irrigation network is important;
- Provision of spare parts for some mechanical equipment is essential to enable the WWTP operators to do the required maintenance;
- Local council should have knowledge transfer strategy in place on the O&M of the WWTP in case key staff retires or relocates;
- Awareness raising activities on TWW through thorough engagement with community members can change community perceptions on TWW reuse;
- A financial sustainability study for the operations of the WWTP should be performed;
- On-site de-sludging to decrease the operational costs should be realized such as installing a de-watering unit;
- Alternative energy sources for the WWTP such as solar energy should be explored.

8. Conclusion

In conclusion, the activities of the major and minor interventions significantly improved the performance of the WWTP of Beit Dajan and were necessary to obtain TWW that is of adequate quality to irrigate the crops of Beit Dajan's farmers. Although the Palestinian Standards regarding turbidity has not been reached, once the sand filters are operational again, the TSS and turbidity and likely also BOD and COD will further decrease.