MENAWARA

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. Ramtha WWTP, Jordan

Responsible partner: NARC

18/01/2024

Menawara is a project funded by the EU unded the ENI CBC Med programme. Its total budget is €2.901.546,93 out of which €2.611.392,23 as EU funding (90% contribution).

This document has been produced with the financial assistance of the European Union under the ENI CBC Mediterranean Sea Basin Programme. The contents of this document are the sole responsibility of NARC and can under no circumstances be regarded as reflecting the position of the European Union or the Programme management structures.

The 2014-2020 ENI CBC Mediterranean Sea Basin Programme is a multilateral Cross-Border Cooperation (CBC) initiative funded by the European Neighbourhood Instrument (ENI). The Programme objective is to foster fair, equitable and sustainable economic, social and territorial development, which may advance cross-border integration and valorise participating countries' territories and values. The following 13 countries participate in the Programme: Cyprus, Egypt, France, Greece, Israel, Italy, Jordan, Lebanon, Malta, Palestine, Portugal, Spain, Tunisia. The Managing Authority (JMA) is the Autonomous Region of Sardinia (Italy). Official Programme languages are Arabic, English and French. For more information, please visit:

www.enicbcmed.eu.

The European Union is made up of 28 Member States who have decided to gradually link together their know-how, resources and destinies. Together, during a period of enlargement of 50 years, they have built a zone of stability, democracy and sustainable development whilst maintaining cultural diversity, tolerance and individual freedoms. The European Union is committed to sharing its achievements and its values with countries and peoples beyond its borders.

TABLE OF CONTENT

ABBREVIATIONS AND ACRONYMS

Acronym	Description
BOD5	Biological Oxygen Demand after 5 days
CFU	Colony Forming Unit
CENTA	Andalusian Public Foundation Centro de las Nuevas Tecnologías del Agua
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
NCW	Non-conventional water
NTU	Nephelometric Turbidity Unit
SVI 30	Sludge Volume Index after 30 minutes
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TWW	Treated Wastewater
WP	Work Package
WWTP	Wastewater Treatment Plant
NARC	National Agricultural Research enter

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 Reuse 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).

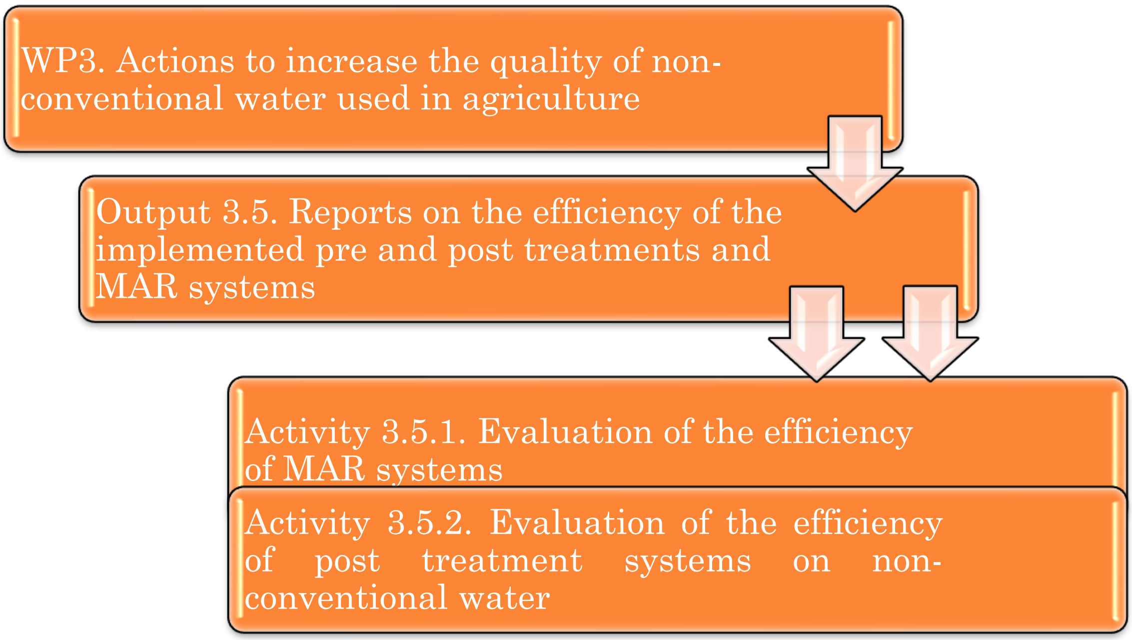

Figure 1. Infographic on the context of this technical report.

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 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 Ramtha WWTP, Jordan, 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 Jordan (Standards, Regulations & Legislation for Water in Jordan), the O&M activities carried out and the lessons learned over the period of 2020 to 2023, under this output 3.5, 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 complimentary 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) section 2 includes an introduction and general overview of the WWTP after the implementation of both the minor and major intervention; ii) section 3 reports the National quality standard for water reuse in agriculture in Jordan 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 Ramtha WWTP; iii) methodology including material and methods will be detailed in Section 4; iv) in Section 5 the water quality will be assessed, including discussion of results obtained; 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) will then be summarized in this report.

2. Area of intervention

Al Ramtha is situated in the far northwest of Jordan. It covers 40 km² in a flat location 85 km north of Amman, with a population of 164000 (2017). The climate of Al Ramtha has transitive climatic characteristics between the most humid zone of the country and the desert. The summer is hot and dry with mean daily temperature ranging from 19 to 31 °C. The mean annual minimum and maximum temperatures are 11.6 and 25 °C, respectively. Rainfall occurs mainly from November to March, with mean annual rainfall (2005–2019) at Ramtha rainfall station of 213. mm.

The Ramtha treated wastewater (RTWW) is used to irrigate surrounding agricultural lands, which are cultivated with forage.

Ramtha TWW Research Station in Jordan has been chosen as MENAWARA's intervention site. The design of the post-treatment system in Ramtha Intervention Site aimed at enhancing the processes of water quality. Following previous discussions and definition with the technicians and experts working for NARC and CENTA and according to the "fit for purpose", principle, the treatment system to be implemented included a post-treatment train to the existing storage tank, based on filtration process using pressure sand filters and disc filters, subsequent disinfection stage by application of ultraviolet radiation and maintenance disinfection by adding sodium hypoclorite.

The facilities were planned with a treatment capacity of 500 m3/d. The design should have been adequate to allow the reuse of the treated water for irrigation of agricultural crops. Therefore, its main objective was to define its necessary processes, facilities and equipment. The following requirements have also been considered as basic objectives when designing and projecting this project:

- Providing a quality of execution to civil works, equipment and facilities that allow a value for money that fits this type of works, paying particular attention to the task that they are going to perform.

- Providing facilities with sufficient flexibility to facilitate operating manoeuvres and achieve low O&M costs.

2.1 Post-treatment

Figure 2: Overview of Ramtha WWTP, including treatment units

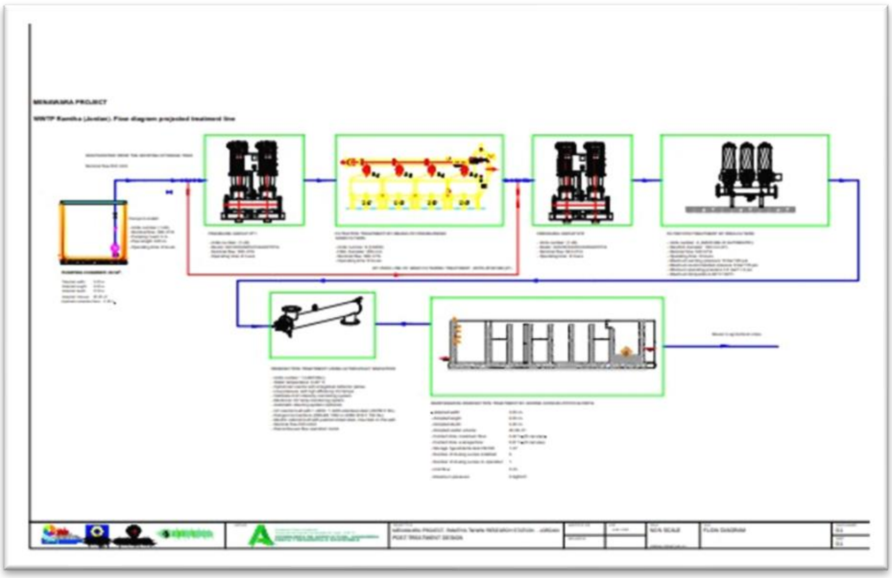

Figure 3 Schematic representation of WWTP of Ramta research station including new filtration items indicate newly constructed assets by the MENAWARA major interventions

It has been chosen to design a tertiary treatment line for the reclamation of the secondary treated wastewater from the WWTP Ramtha and accumulated in an existing storage pool. The tertiary treatment train is composed of a filtration treatment through pressure sand and disc filters, followed by a subsequent disinfection stage by means of the action of ultraviolet radiation and maintenance chlorination (chlorination labyrinth). As a stage prior to the water reclamation installation, it was necessary to have one piping chamber (1+R) at the outlet of the existing storage tank. Its objective was double: on the one hand, it serves to laminate possible variations in the effluent flow of the WWTP and, on the other, it allows water with a more constant quality to be introduced into the reclamation treatment train. A pressure group was also installed to achieve the pressures required by the filtering system

General overview of the WWTP after the implementation of both the minor and major interventions.

Figure 3. Location of Ramtha WWTP and Treated Wastewater Research Station, in Jordan.

3. Standard for water reuse in agriculture in Jordan

Jordan controls water reuse activities through country-wide standards. The legal basis governing use of reclaimed water is encoded in the Jordanian Standards 893/19957. A translation of these standards is provided in Appendix A. Numerical criteria are provided for seven "uses" of reclaimed water in JS 893/1995:

1. Irrigation of vegetables eaten cooked
2. Irrigation of fruit trees, forests, industrial crops, and grains
3. Discharge to streams and catchment areas
4. Artificial recharge of groundwater
5. Use in aquaculture (fish hatcheries)
6. Irrigation of public parks
7. Irrigation of fodder

Include the National quality standard for water reuse in agriculture in Jordan 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 Ramtha WWTP

Table 1. Numerical standards for use of treated wastewater in Jordan number (893/1995)

Quality parameters	Vegetables eaten uncooked	Fruit trees, forest industrial crops and grain	Dischar gesto wadis	Artificial recharge	fisheries	Public parks	Fodder
BOD5	150	150	50	50	Na	50	250
COD	500	500	200	200	NA	200	700
DO	>2	>2	>2	>2	>5	>2	>2
TDS	2,000	2,000	2,000	1,500	2,000	2,000	2,000
TSS	200	200	50	50	25	50	250
Ph	6-9	6-9	6-9	6-9	6.5-9	6-9	6-9

Color	NA	NA	75	75	NA	75	NA
FOG	8	8	8	Nil	8	8	12
Phenol	0.002	0.002	0.002	0.002	0.001	0.002	0.002
MBAS	50	50	25	15	0.2	15	50
NO3-N	50	50	25	25	NA	25	50
NH4-N	NA	NA	15	15	0.5	50	NA
T-N	100	100	50	50	NA	100	NA
PO4-P	NA	NA	15	15	NA	15	NA
Cl	350	350	350	350	NA	350	350
SO4	1,000	1,000	1,000	1,000	NA	1,000	1,000
CO3	6	6	6	6	NA	6	6
HCO3	520	520	520	520	NA	520	520
Na	230	230	230	230	NA	230	230
Mg	60	60	60	60	NA	60	60
Ca	400	400	400	400	NA	400	400
SAR	9	9	9	9	NA	12	9
RC	0.5	NA	NA	NA	NA	0.5	NA
Al	5	5	5	1	NA	5	5
As	0.1	0.1	0.05	0.05	0.05	0.1	0.1
Be	0.1	0.1	0.1	0.1	1.1	0.1	0.1
Cu	0.2	0.2	0.2	0.2	0.04	0.2	0.2
F	1.0	1.0	1.0	1.0	1.5	1.0	1.0
Fe	5.0	5.0	2.0	1.0	0.5	5.0	5.0
Li	2.5	5.0	1.0	1.0	NA	3.0	5.0
Mn	0.2	0.2	0.2	0.2	1.0	0.2	0.2
Ni	0.2	0.2	0.2	0.2	0.4	0.2	0.2
Pb	5.0	5.0	0.1	0.1	0.15	0.1	5.0
Se	0.02	0.02	0.02	0.02	0.05	0.02	0.02
Cd	0.01	0.01	0.01	0.01	0.015	0.01	0.01
Zn	2.0	2.0	15	15	0.6	2.0	2.0
CN	0.1	0.1	0.1	0.1	0.005	0.1	0.1

Cr	0.1	0.1	0.05	0.05	0.1	0.1	0.1
Hg	0.001	0.001	0.001	0.001	0.00005	0.001	0.001
V	0.1	0.1	0.1	0.1	NA	0.1	0.1
Co	0.05	0.05	0.05	0.05	NA	0.05	0.05
B	1.0	1.0	2.0	1.0	NA	3.0	3.0
Mo	0.01	0.01	0.01	0.01	NA	0.01	0.01
FCC (MPN/100ml)	1,000	NA	1,000	1,000	1,000	200	NA
Pathogens	NA	NA	NA	NA	100,000	Nil	NA
Amoeba and *Giardia* (cyst/l)	<1	NA	NA	NA	NA	Nil	NA
Nematodes (egg/l)	<1	NA	<1	NA	NA	<1	<1

[a] Depends on type of fish, pH, and temperature.

[b] Trace elements and heavy metals values assume annual irrigation of 10,000 m^3/ha.

[c] BOD5 in waste stabilisation pond is filtered, but in mechanical treatment plant is non filtered.

[d] Unit weight measured by unit of Platen Cobalt.

[e] Contact time > 30 min.

[f] Most probable number/100 ml.

[g] One cyst/l

[h] Mean *Ascaris, Ancylostoma* and *Trichuris*

[i] *Salmonella*/100 ml

BOD5 = Biological oxygen demands (five days).
COD = Chemical oxygen demand.
DO = Dissolved oxygen.
FCC = Faecal coli form count.
FOG = Fat, oil and grease.
MBAS = Methylene blue active substance.
RC = Residual chlorine.
SAR = Sodium adsorption ratio.
TDS = Total dissolved solids.
TSS = Total suspended solids.
T-N = Total nitrogen.
NA = Not applicable

4. METHODOLOGY

Evaluation of the filtration unit performance at Ramtha Research Station

Water samples were collected by NARC team before and after the sand filter as well as before and after the UV unit at the new infiltration unit which was installed by MENAWARA project to enhance water quality.

Turbidity and Total Suspended Solids (TSS) Analysis

The filtration unit's performance, as summarized in Table 2, was assessed based on the reduction of Turbidity and Total Suspended Solids (TSS) in water samples. The data indicated a significant decrease in both turbidity and TSS after passing through the sand filter. For example, the turbidity values decreased from a high of 25 to as low as 2.31, and the TSS values showed a reduction from 16 ppm to 4 ppm. These results demonstrate the filter's effectiveness in removing particulate matter from the water.

The variations in turbidity and TSS before and after filtration across different dates suggest that the system consistently improves water quality, albeit with fluctuating efficiency. This fluctuation could be influenced by factors such as the initial water quality or changes in the sand filter media over time.

BOD, COD, *and E. coli* Analysis

Table 3 presents the Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and *E. coli* levels in water samples before and after treatment. Notably, the sand filter reduced the BOD from 33 mg/L to 24 mg/L and the COD from 104 mg/L to 62 mg/L. However, the E. coli count, a critical indicator of water safety, was significantly reduced from 470 per 100ml to 327 per 100ml post-filtration and further to 21 per 100ml after the UV treatment. This dramatic reduction in *E. coli* levels after UV treatment highlights the importance of incorporating a multi-barrier approach in water treatment processes, especially when the goal is to achieve higher water standards.

In conclusion, the subsurface irrigation system demonstrated consistent water distribution, a key factor for its successful application in agriculture. The filtration unit, on the other hand, effectively reduced turbidity, TSS, and

E. coli levels in the water, confirming its utility in improving water quality for various uses. The integration of UV treatment with sand filtration proved to be particularly effective in mitigating microbiological contamination, a vital aspect of ensuring water safety. These findings have significant implications for the optimization of irrigation systems and water treatment processes in agricultural practices.

Table 2. The TSS (ppm) and turbidity tests for the water samples after several trials of changing the filter's sand size.

Date	TSS before sand filter	TSS after sand filter	Turbidity Before sand filter	Turbidity after sand filter
25/10/2022	16	9	10.85	6.99
11/11/2022	12	7	12.65	4
21/11/2022	14	8	25	3.39
28/11/2022	11	4	15.11	2.31

Table 3. Water content from *E. coli* per CFU/100 ml), COD, and BOD before and after filtration unit.

Water Sample	*E.coli* (CFU/100 ml)	COD mg/L	BOD mg/L
Water from the treatment plants before the sand filter	470	62	24
Water after sand filter	327	104	33
Water after UV unit	21	-	-

Also the sand filter reduced the *E, coli* by 30.4 % and the UV reduced the *E.col about* 94% which is excellent impact on water quality

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 Ramtha's WWTP. Report data obtained from the NARC laboratory are shown in Table 2. The New filtration unit interventions performed on the WWTP in Ramtha were necessary to obtain the overall functioning and performance of the WWTP. It can be observed that, regarding the efficiency for the removal of TSS, the sand filters has reduced the turbidity of water by 84.7% and has reduced the TSS by 72.73 % since the moment of its installation in 2022, NO breakdown or significant operational problems have occur.

Figure 3. Evaluation of the Filtration Unit Performance at Ramtha Research Station

6. Operation and maintenance

This Section details the O&M activities carried out in the implemented filtration unit (sand filter, chlorination unit and UV disinfection) post-treatments.

An Operation and maintenance O&M activity was held on 8th of January 2022, during the training of all the operators on the pre-treatment unit of Ramtha Research Station. The topics of this training session included as follows:

- Definition of the mechanical parts of the post-treatment unit;
- Operation of the post-treatment filtration unit including the UV units;
- Operation of the flushing system automatically and manually.
- The operators were also trained on the operation and maintenance of the Post-treatment implemented.
- The topics covered included all the units of post-treatment: sand filters, disc filters, UV unit and pressure groups. (Figure 4). The topics covered were as follows:
- Definition of the mechanical parts of sand filters, UV unit 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:
- Pressure mode II) timing mode III) manual mode;
- Potential operational and technical impacting performance of sand and disc filters;
- Operation of the bypass line. The chlorination unite was installed to be a standby when the chlorination at the treatment plant is not working which is rarely happened.

Figure 4. Training on operation and maintenance of the 8 installed pressured sand filters

7. Lessons learned

The lessons learned and recommendations for up-scaling the post treatments implemented at the rural/local level from the installation of filtration unit at Ramtha research Station are as follows:

• The sand filtration unit demonstrated significant efficiency in reducing turbidity and Total Suspended Solids (TSS) in water samples;
• Turbidity values decreased from 25 to as low as 2.31, and TSS values showed a reduction from 16 ppm to 4 ppm, showcasing the filter's capability in removing particulate matter from water;
• Fluctuations in turbidity and TSS reduction across different dates suggest consistent improvement in water quality, but efficiency may vary. Factors such as initial water quality and changes in the sand filter media could contribute to these fluctuations;
• The integration of UV treatment with sand filtration effectively reduced *E. coli* levels, emphasizing the importance of a multi-barrier approach for ensuring water safety;
• *E. coli* count decreased significantly from 470 CPU/100ml to 21

CPU/100ml after the combined sand filtration and UV treatment;

- The sand filter reduced *E. coli* by 30.4%, and the UV unit further reduced *E. coli* by 94%, showcasing a substantial impact on microbiological contamination and overall water quality enhancement;
- The subsurface irrigation system demonstrated consistent water distribution, a crucial factor for successful agricultural applications;
- The findings have significant implications for optimizing irrigation systems and water treatment processes in agricultural practices, ensuring improved water quality for various uses;
- The new filtration unit interventions at Ramtha's WWTP effectively reduced turbidity by 84.7% and TSS by 72.73%, indicating a successful overall functioning of the WWTP; since its installation in 2022, no breakdowns or significant operational problems have occurred, highlighting the reliability of the filtration unit;
- The training session on the operation and maintenance of the filtration unit covered mechanical parts, electrical panels, and operational modes of sand filters, UV unit, and pressure pumps. WE did not operate chlorination unit during the previous period because chlorination unit at Ramtha Treated Wastewater plant was working very well and no need to add extra chlorine.

8. Conclusion

In conclusion, the evaluation of the filtration and disinfection units performance at Ramtha Research Station highlights the importance of a holistic approach, incorporating various treatment methods for comprehensive water quality improvement. Additionally, continuous training and monitoring are essential for sustaining the optimal performance of the filtration unit. Also, by enhancing the water quality, the farmers can use surface or sub-surface irrigation without clogging problems and with higher water productivity.