



Towards Sustainable Treatment and Reuse of Wastewater in the Mediterranean Region

Capitalization Plan (Output 2.5)

31 October 2023

The AQUACYCLE project is funded and supported by the European Union through the ENI CBC Mediterranean Sea Basin Programme under the Grant Contract A_B41_0027_AQUACYCLE.
Project duration: 50 months (September 2019 – October 2023)



Towards Sustainable Treatment and Reuse of Wastewater in the Mediterranean Region

ENI CBC MED Grant Contract

A_B41_0027_AQUACYCLE

<http://www.enicbmed.eu/projects/aquacycle/>



Capitalization Plan (Output 2.5)

Contributors



Dirk De Ketelaere, Anna Spiteri (Editors)
Integrated Resources Management Co Ltd, (IRMCo), Malta
www.environmentalmalta.com



CERTH
CENTRE FOR
RESEARCH & TECHNOLOGY
HELLAS

Anastasios Karabelas, Plakas Konstantinos, Ioannis Manakos, Angeliki Fotiadou, Avgi Karastogiannidou, Eleanna Pana, Vasilis Chatzis, Christos Kalogeropoulos
Centre for Research & Technology Hellas (CERTH), Greece
<https://www.certh.gr/>



الجامعة اللبنانية
Lebanese University

Ahmad El Moll, Mohamad Khalil, Tawfik AL-Naboulsi, Fatima Yahya
Faculty of Public Health & Doctoral School of Science & Technology, Lebanese University (UL), Lebanon
<https://www.ul.edu.lb/>



Fadel M'Hiri, Khitem Mensi, Anis Ghattassi, Safa Chaabane
Centre International des Technologies de l' Environnement de Tunisie (CITET), Tunisia
<http://www.citet.nat.tn>



Hamadi Kallali, Yasmin Cherni, Samira Melki, Mohamed Ali Wahab, Mariem Doggui, Raja Jomni
Centre des Recherches et des Technologies des Eaux (CERTE), Tunisia
<http://www.certe.rnrt.tn/>



Isabel Oller Alberola, Inmaculada Polo López, Samira Nahim Granados
Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas, Plataforma Solar de Almeria (CIEMAT-PSA), Spain
<http://www.psa.es/>



Pedro Jose Simon Andreu, Roman Lopez
Entidad de Saneamiento y Depuración de la Región de Murcia (ESAMUR), Spain
<http://www.esamur.com/>

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 CERTH and IRMCo 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.enicbcmmed.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 CONTENTS

Executive Summary	6
1. Project Legacies	7
1.1 e-training platform on APOC system	8
1.2 WebGIS to draw up optimum action plans for the reuse of treated effluent	10
1.3 Pilot demo-sites of APOC system	14
1.4 3-D Models of APOC system	16
1.5 Logistics for the participatory drawing up of action plans for the reuse of treated effluent	17
1.6 MedAPOC Charter	18
1.7 Scientific publications	19
1.8 Opinion Articles and e-Newsletters	22
1.9 AQUACYCLE My Autobiography	24
1.10 AQUACYCLE channel on YouTube	26
2. Capacity Building Achievements	30
2.1 Certified APOC Users	31
2.2 Postgraduate research degrees awarded for research conducted in the context of AQUACYCLE	33
2.3 Promoting the role of women in high-level research	41
3. AQUACYCLE Key Achievements	50

LIST OF TABLES

TABLE 1: PROJECT LEGACIES, TARGET GROUPS AND ACCESS BEYOND PROJECT DURATION	7
TABLE 2: WEBGIS LAYERS AND CRITERIA APPLIED FOR DEDDEH KOURA, NORTH LEBANON	11
TABLE 3: ACTUAL IRRIGATED AREAS IN ENVIRONS OF DEDDEH KOURA, NORTH LEBANON	13
TABLE 4: POTENTIAL ACTION PLANS REQUIRING 300.000 M³ OF TREATED EFFLUENT	13
TABLE 5: EDITIONS OF MEDAPOC CHARTER AND THEIR DOWNLOAD LINKS FROM PROJECT WEBSITE	18
TABLE 6: TITLES OF OPINION ARTICLES, MONTH OF ISSUE AND DOWNLOAD LINKS FROM PROJECT WEBSITE	22
TABLE 7: SEQUENCE OF AQUACYCLE E-NEWSLETTERS, MONTH OF ISSUE AND DOWNLOAD LINKS FROM PROJECT WEBSITE	23
TABLE 8: BRIEF DESCRIPTION OF VIDEO CLIPS AND THEIR RESPECTIVE LINK ON THE DEDICATED AQUACYCLE CHANNEL ON YOUTUBE	26
TABLE 9: CAPACITY BUILDING ACHIEVEMENTS DURING PROJECT LIFETIME, RECIPIENTS AND QUANTIFIED NUMBER OF RECIPIENTS	30
TABLE 10: CERTIFIED APOC USERS	32
TABLE 11: WOMEN RESEARCHERS INVOLVED IN AQUACYCLE PROJECT	41
TABLE 12: AQUACYCLE ACHIEVEMENTS IN RELATION TO TARGETS SET BY ENI CBC MED PROGRAMME	50
TABLE 13: AQUACYCLE ACHIEVEMENTS IN RELATION TO THE ORIGINALLY FORESEEN QUANTIFIED TARGET OUTPUTS	53

LIST OF FIGURES

FIGURE 1: SCHEMATIC OVERVIEW OF THE APOC SYSTEM ON THE E-LEARNING PLATFORM	8
FIGURE 2: NEWS POST ANNOUNCING THE LAUNCHING OF THE E-TRAINING PLATFORM	9
FIGURE 3: ACCESS PAGE TO THE WEBGIS (HTTP://WEB-GIS-IRRIGATION.ITI.GR/)	10
FIGURE 4: WEBGIS DISPLAYS PIXELS (IN BLACK) THAT SATISFY ALL THE EXAMPLE CRITERIA WITHIN THE ENVIRONS OF DEDDEH KOURA, NORTH LEBANON	11
FIGURE 5: WEBGIS OUTPUT IMPORTED ONTO PGIS LANDING PAGE FOR DEDDEH KOURA, NORTH LEBANON	12
FIGURE 6: CURRENTLY IRRIGATED AREAS AND TYPE OF IRRIGATION APPLICATION IN THE ENVIRONS OF DEDDEH KOURA, NORTH LEBANON	12
FIGURE 7: SATELLITE IMAGES OF THE LOCATION OF THE PILOT DEMO SITES IN LEBANON, SPAIN AND TUNISIA	14
FIGURE 8: BILLBOARD SET UP AT THE PILOT DEMO UNIT IN BLANCA IN THE MURCIA REGION OF SPAIN	14
FIGURE 9: COVER IMAGE ACCOMPANYING THE NEWS POST ON THE PROJECT WEBSITE FOLLOWING THE AWARD TO TENDER FOR THE CONSTRUCTION OF A PILOT DEMO-UNIT AT DEDDEH, KOURA IN NORTH LEBANON	15
FIGURE 10: MINIATURE PROTOTYPE OF THE APOC SYSTEM DESIGNED BY CERTH	16
FIGURE 11: MINIATURE PROTOTYPE OF THE APOC SYSTEM DESIGNED BY UL	16
FIGURE 12: PGIS LANDING PAGES TO DEMO SITES IN LEBANON, SPAIN AND TUNISIA AND THE ACCESS LINKS	17
FIGURE 13: COVER IMAGE FOR NEWS POST ACCOMPANYING LAUNCH OF FIRST OPINION ARTICLE ON PROJECT WEBSITE	22
FIGURE 14: COVER IMAGES FOR NEWS POSTS INVITING TO SUBSCRIBE TO AQUACYCLE’S E-NEWSLETTERS	23
FIGURE 15: COVER AND TABLE OF CONTENTS OF FIRST TOME OF AQUACYCLE MY AUTOBIOGRAPHY	24
FIGURE 16: COVER AND TABLE OF CONTENTS OF SECOND TOME OF AQUACYCLE MY AUTOBIOGRAPHY	25
FIGURE 17: COVER IMAGE OF NEWS POST ANNOUNCING LAUNCH OF VIDEO CLIPS ON TRAINING-OF-TRAINERS’ EVENT	31
FIGURE 18: AWARD PRESENTED TO CERTIFIED APOC USERS	32
FIGURE 19: COVER IMAGE OF NEWS POST ANNOUNCING AWARD OF PHD DEGREE TO MS AMAL MEJRI	34
FIGURE 20: RACEWAY POND REACTORS OF 5 CM (A) AND 15 CM (B) LIQUID DEPTH. SOURCE: MS AMAL MEJRI PHD THESIS	34
FIGURE 21: GRAPHICAL ABSTRACT OF FE3+-NTA AS IRON SOURCE FOR SOLAR PHOTO-FENTON AT NEUTRAL PH IN RACEWAY PONDS REACTORS. SOURCE: MS AMAL MEJRI PHD THESIS	35
FIGURE 22: COVER IMAGE OF NEWS POST ANNOUNCING AWARD OF RURAL ENGINEER DIPLOMA TO MS JIHENE TAYAH	36
FIGURE 23: COVER IMAGE OF NEWS POST ANNOUNCING AWARD OF MSC DEGREE TO MS FATMA DRIDI	37
FIGURE 24: CLASSIFICATION OF AQUATIC PLANTS	38
FIGURE 25: CLASSIFICATION OF AQUATIC PLANTS	38
FIGURE 26: PHRAGMITES AUSTRALIS (COMMON REED)	39
FIGURE 27: CANNA LUCIFER (CANNA LILY)	39
FIGURE 28: COVER IMAGE OF NEWS POST ANNOUNCING AWARD OF MSC DEGREE TO MS MARIEM DOGGUI	40
FIGURE 29: MEET DR. INMACULADA WHO HAS A PASSION FOR RESEARCH ON MICROBIAL PATHOGENS	42
FIGURE 30: SOLAR PILOT PLANTS AND HIGHLY EQUIPPED LABORATORY FACILITIES FOR THE MICROBIAL ANALYSIS OF WATER SAMPLES AT CIEMAT-PSA	43
FIGURE 31: PRAISE OF WOMEN RESEARCHERS IN TUNISIA MARKING WOMEN’S DAY ON 8 MARCH 2022	44
FIGURE 32: DR. YASMIN CHERNI, WHO JOINED CERTE TEAM IN AQUACYCLE AS A POST-DOC IN 2020	46
FIGURE 33: MRS. MARIEM DOUGGUI, WHO JOINED CERTE TEAM IN AQUACYCLE AS AN MSC STUDENT IN 2020	46
FIGURE 34: DR. AMAL MEJRI, WHO JOINED CERTE TEAM IN AQUACYCLE AS A PHD CANDIDATE IN 2020	47
FIGURE 35: DR. SAFA CHAABANE, WHO JOINED CERTE TEAM IN AQUACYCLE AS A RESEARCHER IN 2020	47
FIGURE 36: DR. SAMIRA MELKI, WHO JOINED CERTE TEAM IN AQUACYCLE AS A SENIOR RESEARCHER IN 2021	48
FIGURE 37: MRS. RAJA JOMNI, WHO JOINED CERTE TEAM IN AQUACYCLE AS AN ADMINISTRATIVE MANAGER IN 2019	48
FIGURE 38: MRS. KAOUTHER BARGAOUI, WHO JOINED CERTE TEAM IN AQUACYCLE AS A COMMUNITY MANAGER IN 2019	49

Executive Summary

The **AQUACYCLE Capitalization Plan** takes stock of the ENI CBC Med funded project's achievements from two complementary perspectives.

The first chapter collects the **Project Legacies** – which have been aggregated under no less than 10 different headers – together with the targeted recipients and informs on how public access to these legacies will be ensured beyond the project lifetime. Consequently, further details are presented on each of these respective project legacies.

The second chapter informs about the project's **Capacity Building Achievements**, the recipients and the quantified targets reached in terms of the number of Certified APOC users, the number of tertiary degree awards to women in Tunisia for their research related to the project's eco-innovative wastewater treatment system, and a multitude of women researchers who have been highly instrumental in the successful outcomes of the project's research activities and for making the outcomes accessible to a wider public, including society at large.

The final, third chapter reiterates on the Project Key Performance Indicators, which sustains the subtitle of the second volume of **AQUACYCLE My Autobiography: Exceeding on Expectations**.

1. Project Legacies

As an introduction to this first chapter, a schematic overview is provided of the achievements which will remain fully accessible beyond the duration of the AQUACYCLE project. The table below shows the intended target group(s) and how access to the respective project legacies will be ensured. These project legacies have in common that they promote an eco-innovative wastewater treatment system, which consists of 3 components: anaerobic digestion, constructed wetlands and a raceway pond reactor which assures the solar disinfection of the treated effluent through a process known as Photocatalytic Oxidization. The treatment system is abbreviated as the APOC system, reflecting its 3 components.

Table 1: Project legacies, target groups and access beyond project duration

Project Legacy	Target Group(s)	Access beyond project duration
1.1 e-Training Platform on APOC system	Wastewater treatment plant operators & technicians	Commitment by Lead Beneficiary to host and maintain platform for at least 5 years
1.2 WebGIS to draw up optimum action plans for the reuse of treated effluent	Decision-makers, national and local entities involved with water and sanitation	Open Source Software
1.3 Pilot demo-sites of APOC system	Investors and all other target groups	Commitment by partners in Lebanon, Spain, and Tunisia to maintain operation of pilots for at least 5 years
1.4 3-D models of APOC system	Investors and all other target groups	Physical, miniature model permanently displayed at Lead Beneficiary (CERTH) premises and at the Lebanese University (LU)
1.5 Logistics for the participatory drawing up of action plans for the reuse of treated effluent	Decision-makers, national and local entities involved with the drawing up of action plans for the reuse of treated effluent	The logistics have been implemented as PGIS Landing Pages on google/my maps/ where these remain accessible for as long as this url is maintained and remains free of any charges
1.6 MedAPOC Charter	All target groups	Signing up remains functional for as long as the ENI CBC Med platform remains active
1.7 Scientific publications	Scientific Community	No time limit
1.8 Opinion Articles and e-Newsletters	All target groups	Remains accessible for as long as the ENI CBC Med platform remains active
1.9 AQUACYCLE My Autobiography	Society and all other target groups	Remains accessible for as long as the ENI CBC Med platform remains active
1.10 AQUACYCLE channel on YouTube	All target groups	Remains accessible for as long as YouTube channel remains active

1.1 e-training platform on APOC system

One of the foremost legacies of the project takes the form of an e-training platform, which guides on the design and operation of the AQUACYCLE's eco-innovative wastewater treatment system.

The platform is accessed using the link <https://www.etraining-aquacycle.eu>.

Once inside the platform, one can navigate through the various tabs and get acquainted with the features that are being offered. From its Home page and the presentation of the scope of the AQUACYCLE project, the user can select the APOC tab which offers a schematic overview of the APOC System. In this preview of the system, each of the underlying three components are presented in an interactive manner and lead to more detailed information. The user can start off by selecting a particular component from among the Anaerobic Digester, the Constructed Wetland and the Solar Raceway Pond Reactor. This selection opens up into a new tab which provides a general description of the specific component, its accompanying e-manual, important mathematical equations governing the component selected, as well as a list of advantages and disadvantages. The user can then further advance his/her knowledge by watching the individual component-related videos as well as test his/her knowledge by engaging in Multiple-Choice Questions and a fun-styled Crossword.

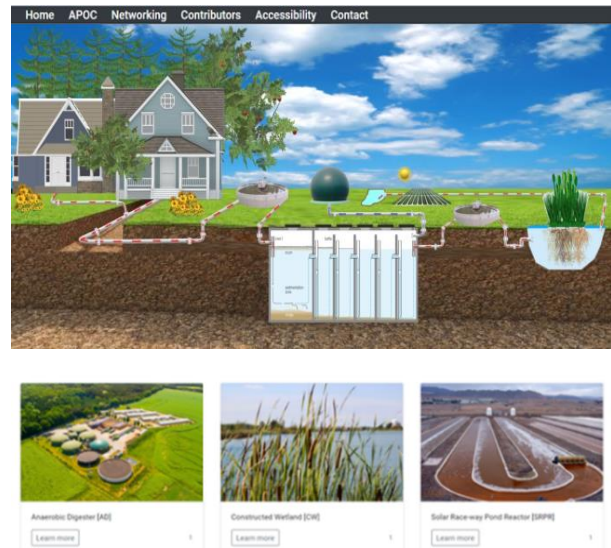


Figure 1: Schematic overview of the APOC system on the e-learning platform

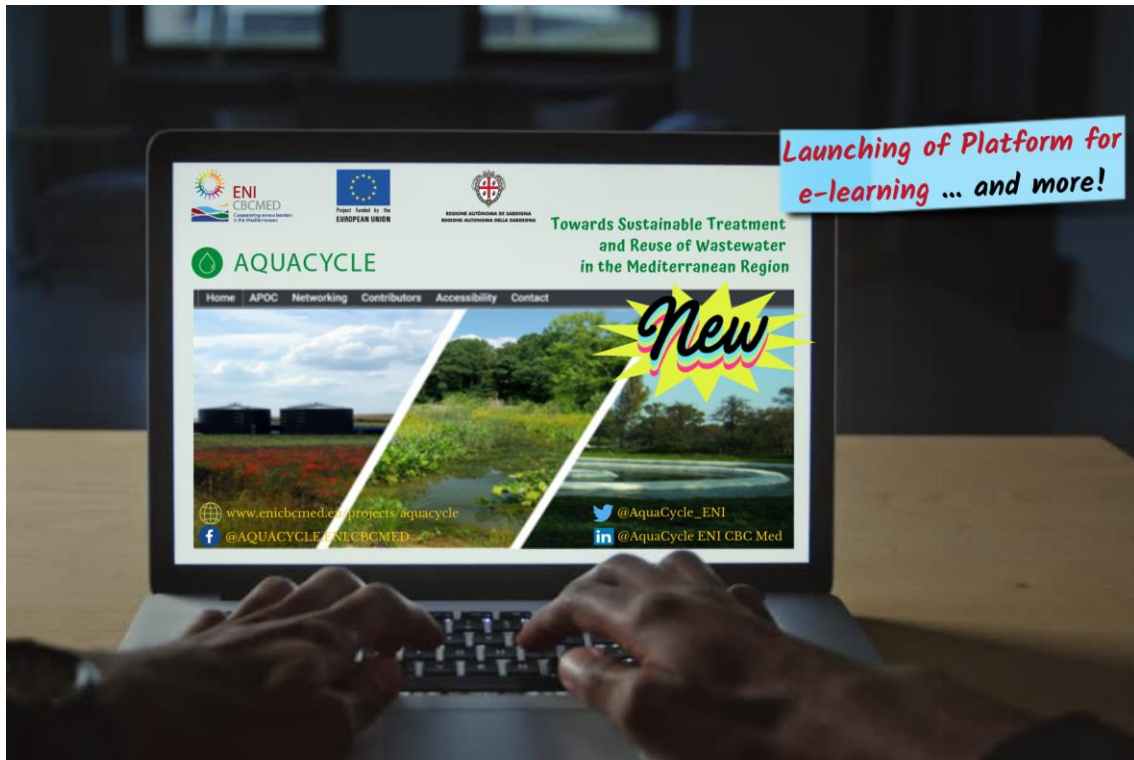
The news post on the project website on 4th August 2021 shown in Fig. 2 marked the public launch of the e-training platform, which was described more extensively in project's 4th e-Newsletter issued in July 2021. Following its launch, additional material, including videos and recorded webinars were added to further enrich the e-training platform.

The platform served as the main tool used during the training-of-trainers event which was organized in the Murcia region of Spain on 22 and 23 February 2023. Subsequently it was used by the partnership to organize further training events which were addressed mainly to wastewater treatment plant operators and technicians. Several university students and other interested parties also took part in these training events.

The e-training platform will remain publicly accessible through the commitment of the project's Lead Beneficiary, CERTH, who will continue to host and maintain the platform for a period of at least 5 years beyond the end of the project in October 2023.

Particularly noteworthy is that aside from the training material, the platform offers users the possibility to communicate and network with other users, including experts on wastewater treatments, from around the world.

AQUACYCLE launches platform for e-training ... and more!



In **AQUACYCLE's 4th e-Newsletter** which was issued to our subscribers in July 2021, **Angeliki Fotiadou, Vasilis Chatzis and Rizos-Theodoros Chadoulis**, from the Centre for Research and Technology, Hellas (**CERTH**) in Greece, proudly reported the launching of an e-training platform.

Its scope is to provide knowledge in the form of guidance and training for all interested parties, from public authorities and educational organizations to private entities and professionals involved with wastewater treatment.

Once connected to the platform, one can learn everything about the assembly of the eco-innovative wastewater treatment - APOC - system and its possible variations, as well as all the characteristics of its three underlying components, the Anaerobic Digester, the Constructed Wetland and the Solar Raceway Pond Reactor. The user can advance his/her knowledge by watching the individual component-related videos as well as test his/her knowledge by engaging in Multiple-Choice Questions and fun-styled Crosswords.

However, in addition to its purpose as a creative tool for online learning and training activities, the platform also enables connecting and establishing cooperation among professional and stakeholders alike. Indeed, the ability to network with other professionals and interested parties from all around the world, should prove a very useful feature of this platform. By signing in and creating a profile, the user has the ability to participate in an online chat forum. By coming in contact with the moderators as well as with other experts and stakeholders around the world, **the user has the means to establish and maintain synergies with other interested parties all around the world!**

To find out more about the platform, read up on **AQUACYCLE's 4th e-Newsletter** which is issued in [Arabic](#), [English](#), [French](#), [Greek](#) and [Spanish](#).

Or, if you wish to skip this suggestion and you would rather find out for yourself about the functionalities of the platform, feel free to follow [this link!](#)

Figure 2: News post announcing the launching of the e-training platform

1.2 WebGIS to draw up optimum action plans for the reuse of treated effluent

The WebGIS decision-support tool is designed to assist in the drawing up of action plans for the reuse of treated wastewater. The tool has been developed and implemented by PhD candidate MSc. Rizos Theodoros Chadoulis, Research Fellow, under the guidance of Dr. Ioannis Manakos, Principal Researcher, who conceptualized, led the design and followed up the realization. Both are employees of the Information Technologies Institute (ITI), Centre for Research and Technology Hellas (CERTH), AQUACYCLE's Lead Beneficiary.

Although its main targeted users are water and sanitation engineers, the open-source software is likely to be found of interest by the scientific community, and in particular by students attending water and sanitation related courses. It is publicly accessible through [this link](#), where the user is invited to log in (see Fig. 3).

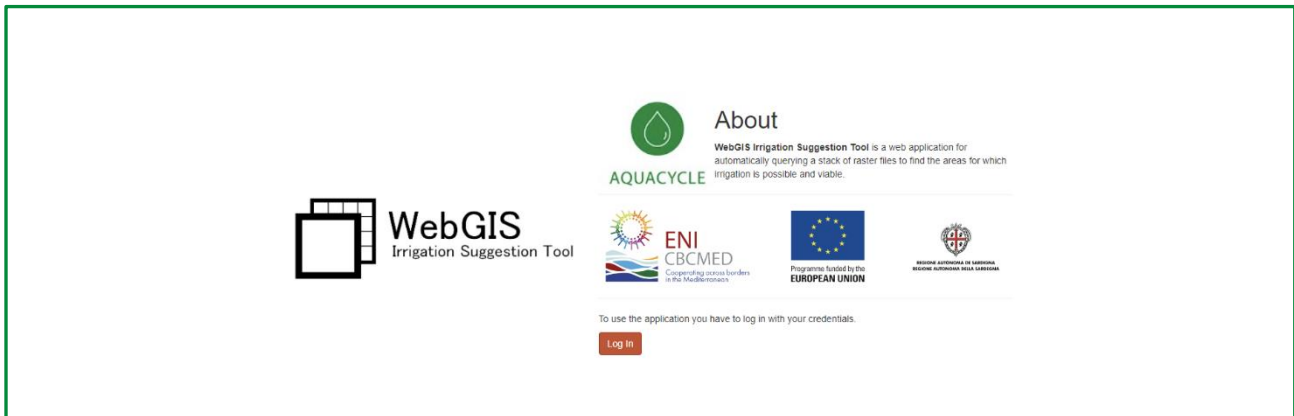


Figure 3: Access page to the WebGIS (<http://web-gis-irrigation.iti.gr/>)

As shown in Fig. 3, a visitor is informed that the Irrigation Suggestion Tool is a web application for automatically querying a stack of raster files to find the areas for which irrigation is possible and viable.

Typically, a user will be required to start by uploading a set of maps available for a given area of interest (this can be any location in the world) that are relevant to the task at hand. All maps are stored in raster format by the WebGIS, i.e. closed polygon shapes are replaced by sets of square pixels. Once the upload is completed, each of the maps can be used to define relevant criteria. A topographic elevation model (DEM) can be queried to e.g. retain only areas at a topographic elevation which would not bring about excessive pumping costs, i.e. to retain only areas to which irrigation water could be supplied in an economically viable manner. Once the user has defined criteria for the respective maps, and presses the 'submit' button, the WebGIS generates the output in a matter seconds.

By way of illustration, the set of maps uploaded for the Deddeh Koura area in North Lebanon and the criteria applied to each of the maps is shown in Table 2. The webGIS output comes as a set of pixels which match all the criteria that have been applied as shown in Fig. 4. In a consequent step, a user can compare the output thus obtained against the existing irrigation areas to find out which of these could be replaced either in part or entirely through the use of treated effluent. Evidently, a user may also wish to extend irrigation with treated effluent to areas where this is deemed possible and viable as guided by the WebGIS output.

The attention of users is drawn to the fact that the output can only be representative of the information that has been uploaded to the WebGIS. As with any decision-support tool, a user is invited to carefully check the degree of accuracy and timeliness of the maps supplied, and should additionally bear in mind that the WebGIS can perform queries only on the basis of the information made available to it.

Table 2: WebGIS layers and criteria applied for Deddeh Koura, North Lebanon

Layer name	Criteria
Elevation	Do not exceed an elevation of 255 metres AMSL (= stay within 25 metres above the topographic elevation of 230 m AMSL of the pilot demonstration unit to avoid excessive pumping costs)
Artificial areas	Exclude all areas except green urban and green sports areas
Agricultural areas	Include only active agricultural food production = exclude urban sprawl areas, abandoned agricultural land and livestock rearing units, e.g. poultry farms)
Wooded lands	Include only agricultural units
Other Land use/Land cover	Exclude all other land use/land cover categories
Soil type	Exclude coastal sand, sand dunes and gravel
Geospatial Bounds	Draw rectangle around location of Deddeh (shown by blue rectangle in Fig. 3)

Once relevant criteria have been entered and the user has defined the geospatial bounds of the area of interest (shown by the rectangle in blue in Fig. 4), the user is prompted to “submit” the query (rectangular button encircled in green in Fig. 4). Within seconds, the WebGIS displays all the pixels within the area of interest which satisfy the criteria as specified by the user are shown in black colour.

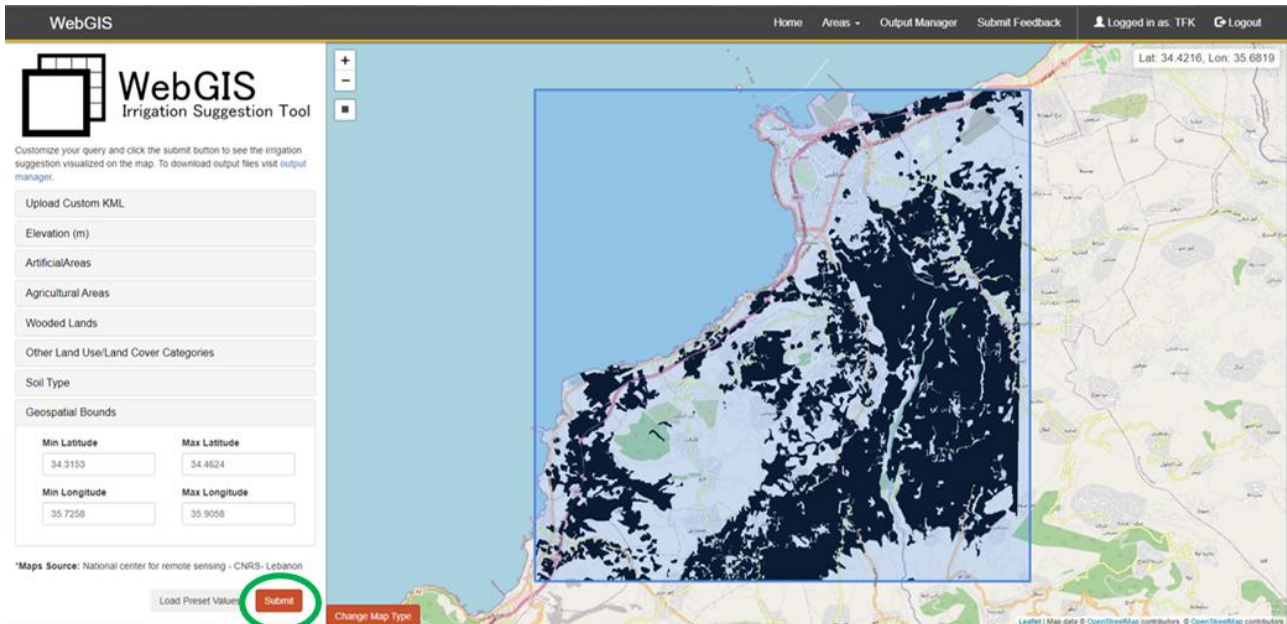


Figure 4: WebGIS displays pixels (in black) that satisfy all the example criteria within the environs of Deddeh Koura, North Lebanon

A further functionality was added to the WebGIS which permits the user to export the raster output into a .kml shape file. This functionality was motivated to enable the AQUACYCLE research teams to import the WebGIS output back onto the PGIS landing pages which had been developed to collect bottom-up inputs towards the drawing up of action plans for the reuse of treated effluent.

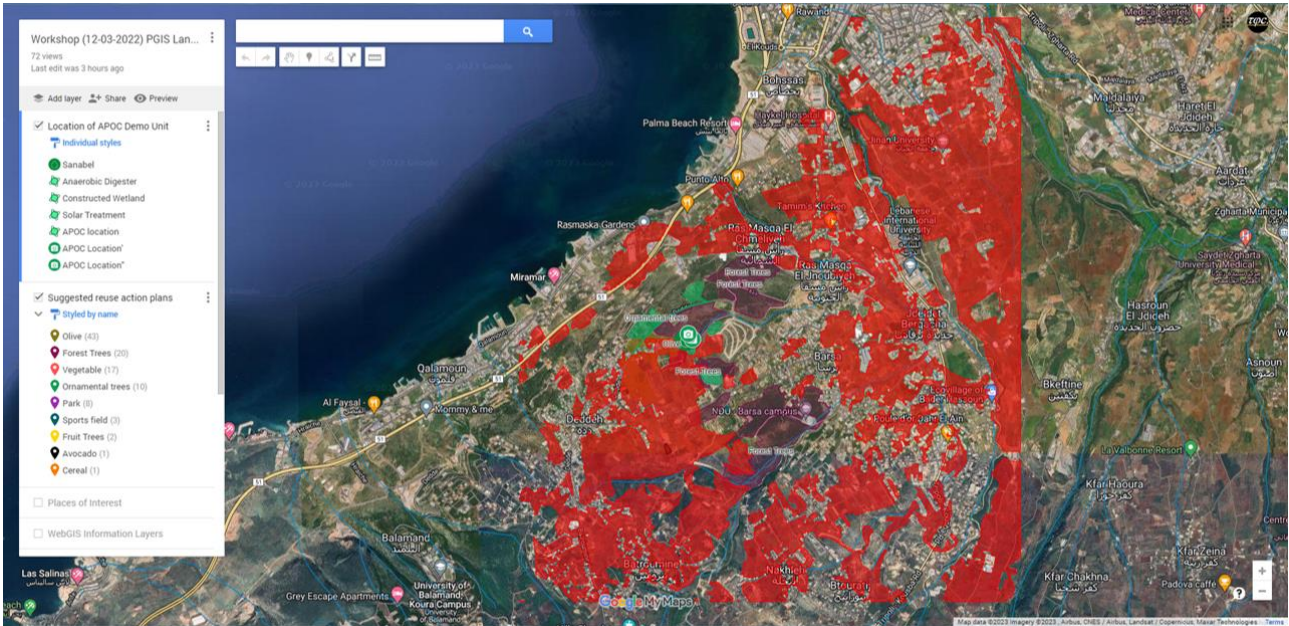


Figure 5: WebGIS output imported onto PGIS Landing page for Deddeh Koura, North Lebanon

In a consequent step, a user can compare the output thus obtained against the existing irrigation areas to find out which of these could be replaced either in part or entirely through the use of treated effluent. Currently irrigated areas in the environs of Deddeh Koura, North Lebanon, are shown in Fig. 6. The total surface of these irrigated areas amounts to just over 209 ha, and the detailed breakdown in relation to the crop types is presented in Table 3.

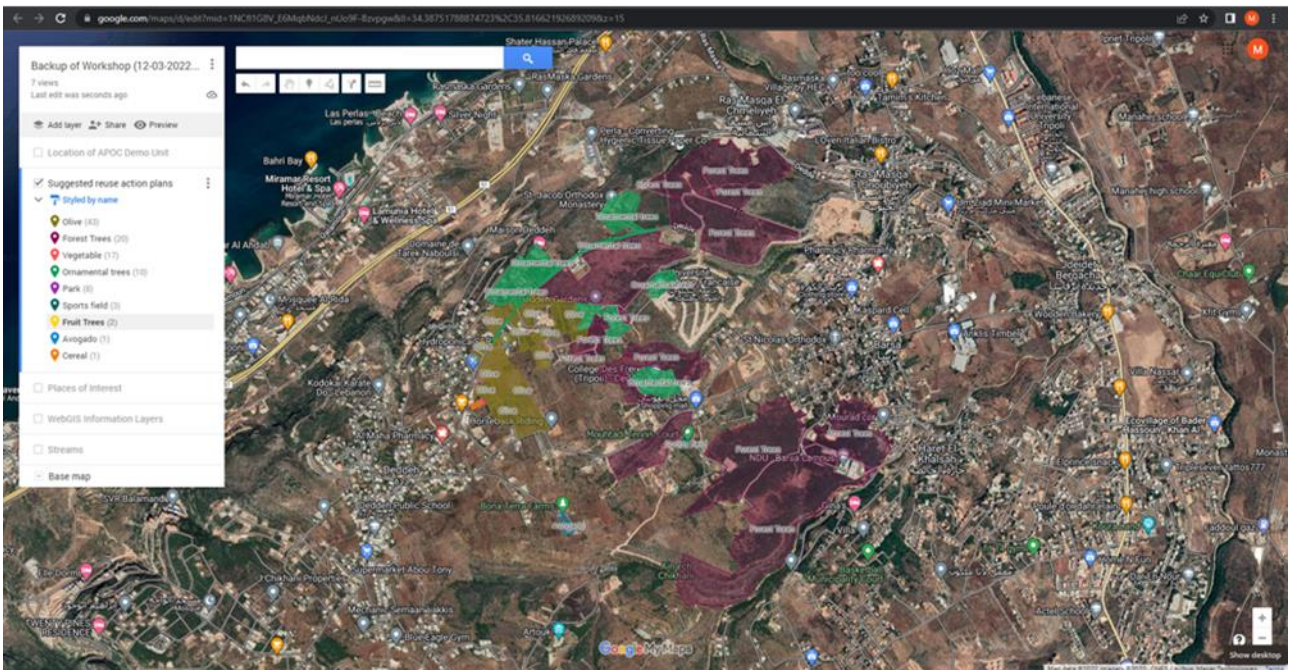


Figure 6: Currently irrigated areas and type of irrigation application in the environs of Deddeh Koura, North Lebanon

Table 3: Actual irrigated areas in environs of Deddeh Koura, North Lebanon

Crop	Area (ha)	Crop	Area (ha)
Avocado	0.75	Ornamental trees	22.939
Cereal	0.184	Park	5.554
Forest trees	141.176	Sports Field	6.187
Fruit trees	2.09	Vegetable	7.081
Olive	23.393	Aggregate Total	209.354

Assuming an annual irrigation volume of 1000 mm per hectare, all of the currently irrigated areas in the environs, together with a further 90 ha of land to reach an action plan with the target volume of 300.000 m³ of treated effluent per annum. However, this may not necessarily be the most optimum action plan.

In the final step to arrive at an optimum action plan for the reuse of treated domestic effluent, the outcome obtained from the Irrigation Support Tool (Fig. 5), which aggregates to an area of 1.470 ha can be overlaid on the map showing the actual irrigated areas on the PGIS Landing Page (Fig. 6) to determine the most viable areas for irrigation to then match an irrigation volume of 300.000 m³ per annum with treated effluent:

Table 4: Potential action plans requiring 300.000 m³ of treated effluent

Action plan based on:	Area (ha)	Required Irrigation volume (m ³)
WebGIS output (areas that can be irrigated in a cost-effective manner)	1.470	1.470.000
Replacing actual irrigation areas with treated effluent	209	209.000
Overlay (crossing of above maps in a GIS environment)	300	300.000

As can be derived from Table 4, there are an infinite number of options to reach an action plan around the environs in Deddeh for the reuse of 300.000 m³ of treated effluent per annum. However, it is clearly logical that an optimum plan would consider (in order of priority):

- 1) Replace areas as indicated by the WebGIS that match areas which are already under irrigation (to replace the irrigation with conventional water resources with treated effluent),
- 2) Add areas as suggested by the local community that match the output of the WebGIS, thereby encouraging a sense of ownership of the resulting action plan, and
- 3) Add further areas to the action plan that are in the closest proximity to the outlet of the treatment plant (resulting in the most cost-efficient irrigation network) up to a volume of 300.000 m³ of treated effluent (the volume that is purported to be available on an annual basis).

1.3 Pilot demo-sites of APOC system

AQUACYCLE's novel treatment system was originally foreseen to be tested in 3 pilot demonstration sites (see Fig. 7), i.e., at a site owned by the real estate company Sanabel in Deddeh, which is located south of Tripoli in Lebanon; at the location of an existing wastewater treatment facility in the Murcia Region of Spain (Blanca); and at a site in the Zaghouan Governorate of Tunisia (Bent Saidane).



Figure 7: Satellite images of the location of the pilot demo sites in Lebanon, Spain and Tunisia

The pilot demo unit in Murcia connects part of the outflow from the existing anaerobic digester at the Blanca facility with 2 constructed wetlands and to a solar raceway pond reactor. In operation for a period extending over approximately one full year, the pilot demo unit featured prominently in this short video clip on the training-of-trainers event organized on site during 22 and 23 February 2023.



Figure 8: Billboard set up at the pilot demo unit in Blanca in the Murcia region of Spain

A news post on the project website in August 2022, entitled “**AQUACYCLE in jubilant mood with the tidings from Lebanon**” and the related communications through the project’s social media accounts spoke volumes. Despite various challenges faced by the research team at the Lebanese University, which strongly delayed the launch of the tender for the pilot demo unit at Deddeh, the tender had been awarded to the Modon Group on 28 July 2022.



Figure 9: Cover image accompanying the news post on the project website following the award to tender for the construction of a pilot demo-unit at Deddeh, Koura in North Lebanon

Some otherwise unforeseen delays occurred during the construction phase, yet also these were successfully resolved through the intermediation of Eng. Hussam Hawwa, founder and CEO of the Water & Wastewater Management Company DIFAF s.a.l, who came up with a revised plan for the installation of the 3 components (anaerobic digester, constructed wetland and solar raceway pond reactor). The revision resulted in a very compact design and respected the request for the new design to maintain the stormwater drainage infrastructure at the site.

It was evident to all the participants at the project’s Final Conference organized during June 2023, that all parties involved are committed to complete the construction of the pilot demo unit before the end of the AQUACYCLE project. Furthermore, the Lebanese University (LU) held extensive technical discussions with their counterparts in Greece (CERTH) and in Spain (ESAMUR and CIEMAT-PSA) with a view to operate and maintain the pilot demo unit beyond the end of the project’s lifetime.

Furthermore, a survey conducted by Dr. Tawfik Al-Naboulsi among the residents in Deddeh, demonstrated their active interest in the eco-innovative aspects of the APOC system. It is especially noteworthy that the resident expressed their keenness to assist in organizing reuse action plans, such as for landscaping purpose of the site and its environs.

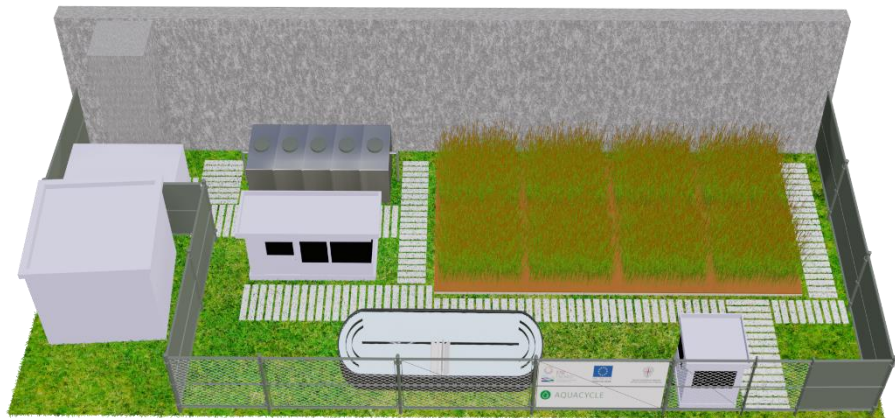
1.4 3-D Models of APOC system

Both the lead beneficiary, the Centre for Environmental Research and Technology Hellas (CERTH), and the Lebanese University (UL) designed a miniature, 3-dimensional prototype of the APOC system. These models will remain displayed at the premises of CERTH and UL and will therefore continue to inform students and visitors alike about the components of the project's eco-innovative wastewater treatment technology. Whereas the 3-D version designed by CERTH is equipped with buttons that can be pressed to light up individual components of the system as shown in Fig. 10, the UL miniature prototype brings a faithful representation of how the individual components have been installed at the pilot demo site in Deddeh Koura in North Lebanon (see Fig. 11).

Figure 10: Miniature prototype of the APOC system designed by CERTH



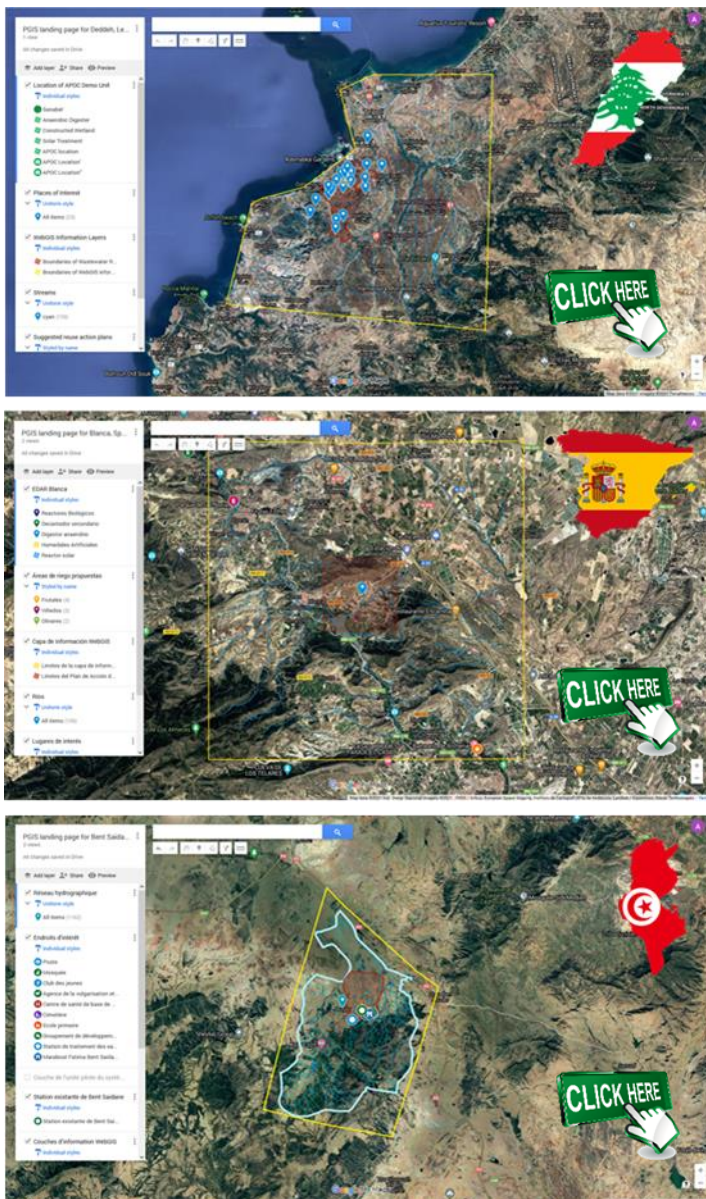
Figure 11: Miniature prototype of the APOC system designed by UL



1.5 Logistics for the participatory drawing up of action plans for the reuse of treated effluent

The bottom-up inputs towards the drawing up of action plans for the reuse of treated effluent was facilitated through the setting up Participatory GIS (PGIS) Landing pages for the respective sites in Lebanon, Spain, and Tunisia on google maps. A detailed description of the process, which included the selection of thematic layers (e.g., surface water drainage network) and the addition of a layer depicting places of interest in the respective areas has been documented in 'Online PGIS environment for participatory planning' (Output 3.4). As illustrated by the figures below, this process permitted to give the three PGIS Landing pages a streamlined 'look' and 'feel', an intentional decision to facilitate and stimulate a cross-border interpretation and exchange of the eventual outcomes of the PGIS Practice sessions organized on the occasion of the second series of stakeholder workshops.

In both Lebanon and Tunisia, computer facilities and internet connection were available to allow the participants to draw their suggested reuse action plans online, while also a printout of the area as a satellite image was made available for orientation purposes.



Finally, the gmail addresses below were created for the participants to share their PGIS entries during the event:

Collection address for Lebanon:
aquacycle.lb@gmail.com

Collection address for Tunisia:
aquacyclecit21@gmail.com

With all the necessary logistics in place, invitation cards were drawn up to announce the event among the respective local communities (by email and by post) as well as through the project website on the platform provided by the ENI CBC Med Programme:

[AQUACYCLE invites local community in Tunisia to draw up reuse action plans of treated effluent](#)

[AQUACYCLE invites local community in Deddeh Koura, Lebanon to draw up reuse action plans of treated effluent](#)

[AQUACYCLE invites local community in Almeria, Spain to draw up reuse action plans of treated effluent](#)

Figure 12: PGIS Landing Pages to demo sites in Lebanon, Spain and Tunisia and the access links

1.6 MedAPOC Charter

The scope of the MedAPOC Charter is to embrace the sustainable use of nonconventional water resources and to promote the transfer and knowledge sharing of AQUACYCLE’s research outcomes at the operational level. In doing so, the Charter aspires to set a common vision for the establishment of a cross-border Mediterranean Wastewater Community.

Rather than bringing the voices of the research teams who designed, tested, and validated the APOC technology, the present Charter brings the voices of farmers and local communities who participated in one or more the project’s stakeholder engagement and outreach activities.

Water stakeholders around the Mediterranean are being invited to sign up to the Charter. In doing so, they become members of AQUACYCLEs Mediterranean Wastewater Reuse Alliance.

A semi-final version of the MedAPOC Charter was issued to mark World Water Day in 2023, with the aim to bring an impetus to its focus in 2023 on accelerating change to solve the water and sanitation crisis. The final version was issued in October 2023.

In the semi-final version, farmers alert to a dire future to sustain their livelihoods in the face of ever dwindling freshwater supplies. Next, they are joined by local community representatives who share their views on the reuse of treated effluent and their expectations of the APOC treatment system. The research in AQUACYCLE also created the opportunity to demonstrate that is perfectly feasible for local communities to have an active role in the drawing up of action plans for the reuse of treated effluent. This is followed by the appraisal of farmers and local communities who participated in Participatory GIS (PGIS) Practice sessions that were organized in Lebanon and in Tunisia with this aim in mind.

The added chapters in the final version of the Charter, bring the views of policy- and decision-making authorities in the water, agricultural, sanitation and health-related sectors on the functionality of an online Irrigation Support Tool. The latter guides on the generation of optimal action plans for the reuse of treated wastewater, based on economic, environmental and social criteria of the user’s choice. It also proved opportune to dedicate a chapter to the level of satisfaction expressed by farmers around the Mediterranean with the current measures put in place by public authorities to combat land and water degradation. Last but not least, the Charter brings the viewpoints expressed by experts and trend-setters in Spain on the reuse of treated wastewater and on the prospects for the APOC technology to meet the recently introduced EU Regulation on the Minimum Requirements for Water Reuse.

Table 5: Editions of MedAPOC Charter and their download links from project website

MedAPOC Charter	Issued	Download Links
Semi-Final Version	Feb 2023	Arabic , English , French
Final Version	Oct 2023	Arabic , English , French

1.7 Scientific publications

Over the duration of the project lifetime, the scientific and technological research advances made by the AQUACYCLE Partnership have been the object of manyfold presentations at seminars, workshops and conferences from the local to the international level.

Abstracts of presentations on the occasion of the stakeholder workshops and webinars organized by the partners in Lebanon, Spain and Tunisia, have been made accessible through the downloads section of the project website. Similarly, also the abstracts of presentations at conferences in which the Partnership took part have been grouped in documents that can be downloaded from the project website. Some examples include (in chronological order of upload to project website):

- [AQUACYCLE Abstracts of presentations First Stakeholder Workshop in Lebanon](#)
- [ODAKtr Seminar on Antibiotic Resistant Bacteria: Occurrence and removal from Urban Wastewater](#)
- [ODAKtr Seminar on Water-Energy-Food nexus in industrial and urban wastewater recovery](#)
- [Abstracts of 2nd National Seminar on Municipal Wastewater Treatment and Reuse in Lebanon 20210215](#)
- [AQUACYCLE Presentation at 3rd Euro-Mediterranean Conference for Environmental Integration 10-13 June 2021](#)
- [AQUACYCLE Presentation in CEMEPE 2021 & SECOTOX Conference 20-24 July 2021](#)
- [Safeguarding the Green and Blue Open Spaces of Malta's Grand Harbour](#)
- [Abstract of Lebanese University presentation at NAWAMED workshop on 29 July 2021](#)
- [CEST2021 Conference AQUACYCLE presentation on APOC system](#)
- [CEST2021 Conference AQUACYCLE presentation on SWOT Analysis](#)
- [CEST 2021 Conference AQUACYCLE presentation on APOC system Tunisia Case Study](#)
- [AQUACYCLE Final Conference Report June 2023](#)

Special mention is merited of scientific publications published during the lifetime of the project.

- 1) Elizangela P. Costa, Melina Roccamante, Patricia Plaza-Bolaños, Isabel Oller, Ana Agüera, Camila C. Amorim, Sixto Malato. Aluminized surface to improve solar light absorption in open reactors: Application for micropollutants removal in effluents from municipal wastewater treatment plants. *Science of the Total Environment* 755 (2021) 142624.
- 2) Towards Sustainable Wastewater Treatment and Reuse (WWTR) in the Mediterranean Region AquaCycle Project: APOC System as an eco-innovative technology for WWTR of Bent Saidane rural locality-NE Tunisia" (EMCEI-2021-P146) ('Book Chapter' in the Proceedings of the 3rd Euro-Mediterranean Conference for Integration, EMCEI 2021).
- 3) Elmoll A., Constructed Wetlands as potential nature-based solutions for water resources management: current state and future prospects, First International Congress on Environment, Biotechnology, Agriculture and Nanotechnology (ICEBAN 2021), CBBC Center, 7-8/4/2021, Tunisia
- 4) Chaabane S., A. Ghattassi, K. Mensi and F. M'hiri "GIS-based multi-criteria analysis for optimal selection of APOC for wastewater treatment in the rural locality of Bent Saidane (NE Tunisia)", 8th International conference on Environmental, Management, Engineering, Planning and Economics (CEMEPE & SECOTOX 2021), Thessaloniki (Greece), 20-24/7/2021.
- 5) Chaabane S., A. Ghattassi, K. Mensi, F. M'hiri, K.V. Plakas, APOC technology as an eco-innovative decentralized sanitation system for wastewater treatment and reuse facilities in the rural locality of Bent Saidane-NE Tunisia, 17th International Conference on Environmental Science and Technology (CEST2021), 1-4/9/2021, Athens, Greece.
- 6) Plakas K.V., A.J. Karabelas, V. Takavakoglou, V. Chatzis, I. Oller-Alberolla, M.I. Polo-Lopez, T. Al-Naboulsi, A. El Moll, H. Kallali, K. Mensi, F. M'Hiri, P. Simon Andreu, Development and demonstration of an eco-innovative system for sustainable treatment and reuse of municipal wastewater in small and medium size communities in the Mediterranean region, 17th International Conference on Environmental Science and Technology (CEST2021), 1-4/9/2021, Athens, Greece.

- 7) Kallali H., K.V. Plakas, A.J. Karabelas, D. De Ketelaere, A. Spiteri, A. El Moll, T. Al-Naboulsi, K. Mensi, S. Jbeli, F. M'hiri, P.J. Simon Andreu, R. Lopez, SWOT analysis of the institutional, policy and regulatory framework governing wastewater treatment and reuse in Tunisia, Lebanon and Spain, 17th International Conference on Environmental Science and Technology (CEST2021), 1-4/9/2021, Athens, Greece.
- 8) Elmoll A., Sustainable management strategies for treated wastewater in Mediterranean region: LEBANON CASE, 1st International Conference, Science Cannot Wait: New Horizons, in Water, Raw Materials, Geology, Ecology, Energy and Environmental and Veterinary Sciences, 29-30/11/2021.
- 9) Cherni Y., H. Kallali, F. Dridi and S. Melki, Performance assessment of APOC technology for rural wastewater treatment: wastewater phytoremediation using macrophytes. First International Congress on Artificial Intelligence & Environmental Biology, 10-12/12/2021, Sousse-Tunisia.
- 10) Cherni Y., H. Kallali, F. Dridi, S. Melki, Performance of APOC system for rural wastewater treatment: use of anaerobic digestion as biotechnological mechanisms for wastewater pre-treatment. 1st International Congress on Artificial Intelligence & Environmental Biology. 10 – 12/12/2021, Sousse, Tunisia.
- 11) Chaabane S., A. Ghattassi, K. Mensi, F. M'hiri, GIS-based multi-criteria analysis of an eco-innovative APOC wastewater treatment and reuse system for irrigation purposes in the rural locality of Bent Saidane (NE Tunisia), Euro-Mediterranean Journal for Environmental Integration 4 (2022) 497-510 (<https://doi.org/10.1007/s41207-022-00329-z>).
- 12) Elmoll A., Water and climate change in the regional, national and international perspective, BOOK TITLE: Sustainable and Circular Management of Resources and Waste Towards a Green Deal, Elsevier, 2022.
- 13) Plakas K.V., Sustainable strategies and technological innovations for the promotion of non-conventional water reuse and management in the Mediterranean region, Congress of Energies and Industrial Process Engineering, 24-25/5/2022, Algiers, Algeria (invited).
- 14) Plakas K.V., Innovative solutions for the promotion of non-conventional water reuse and management in the Mediterranean region, Fourth International Symposium on Materials, Electrochemistry and Environment (CIMEE2022), 22-24/9/2022, Beirut, Lebanon (Hybrid event).
- 15) Plakas K.V., P. Simón Andreu, I. Oller-Alberola, A. Karabelas, APOC demonstration plant for the treatment and reuse of municipal wastewater in the city of Blanca, Spain, 13th Panhellenic Scientific Conference in Chemical Engineering, 2-4/6/2022, Patra, Greece.
- 16) Elmoll A., Eco-innovative technology for wastewater treatment and reuse in Eastern Mediterranean region: Case of Lebanon, Third International Conference Strategies toward Green Deal Implementation - Water and Raw Materials. (ICGreenDeal2022), 2022.
- 17) Plakas K.V., Non-conventional water resources: measures and related opportunities for mitigating the water crisis in the Mediterranean, 2023 Wastewater Reuse Event (virtual), Edition 2023, Session: Treated Wastewater for Agriculture Uses, 22/2/2023 (<https://www.youtube.com/watch?v=UDEl0Aqk9A4>).
- 18) Elmoll A., Eco-innovative technology for wastewater treatment and reuse in MENA region: case of Lebanon, PERSPECTIVE article, Front. Sustain. Sec. Circular Economy 4 (2023) (<https://doi.org/10.3389/frsus.2023.1247009>).
- 19) Hernández-Zanoletty A., P. Simón, S. Nahim-Granados, I. Oller, M.I. Polo-López, K. Plakas, AQUACYCLE project: anaerobic bioreactors combined with natural based solutions and solar open photoreactors for wastewater recovery, Water Innovation & Circularity Conference (WICC), 7-9/6/2023, Athens, Greece.
- 20) Publication in the Parliament Magazine part of the Alliance for a long-term capitalization strategy for the reuse and management of non-conventional water at Mediterranean level (under the MEDWAYCAP project with the support of AQUACYCLE) "MEDWAYCAP: from EU project to Mediterranean Alliance ; Toward an alliance for a long-term capitalisation strategy for the Reuse and Management of Non-Conventional Water at the Mediterranean level) (<https://www.theparliamentmagazine.eu/news/article/the-stepping-stone-to-an-alliance-for-a-longterm-capitalization-strategy-for-the-reuse-and-management-of-nonconventional-water-at-the-mediterranean-level>).
- 21) Cherni Y., K. Djebali, H. Kallali, M.A. Wahab, S. Melki, J. Tayahi, I. Oller, K.V. Plakas, Improving Water Security and Sanitation in Rural Areas: Comparative Evaluation of TiO₂ and Photo-Fenton Processes for Rural Wastewater Treatment and Reuse. Euro-Mediterranean Journal for Environmental Integration (In press).

- 22) Cherni Y., H. Kallali, S. Melki, K.V. Plakas, M.A. Wahab, Innovative Wastewater Treatment for Rural Areas: Anaerobic Digestion and Constructed Wetland Solutions, CLEAN -Soil, Air, Water (under review).
- 23) M. Douggui, S. Melki, H. Kallali, S. Hechmi, Y. Cherni, K.V. Plakas, Integrating GIS and Fuzzy-AHP for Wastewater Management Decision-Making in Rural Areas: A Case Study of the El Fahes Region in Northeast Tunisia, Geocarto International (under review).

1.8 Opinion Articles and e-Newsletters

The Lebanese University in the AQUACYCLE partnership spearheaded the effort to draw up Opinion Articles with the aim to sensitise policy- and decision-makers in Lebanon to dire situation in the country’s water and sanitation sector and the consequent impact of this on the livelihood of rural communities.

In their initial opinion paper, entitled “The use of treated wastewater as a solution to address the impacts of climate change in Lebanon and MENA region”, the authors draw the attention to the plight of rural communities in the Akkar plain of North Lebanon.



Figure 13: Cover image for news post accompanying launch of first Opinion Article on project website

The appraisal by Martin Heibel, Communication Manager within the Managing Authority in his email of 9 November 2020: “Great reading but also important call to Lebanese authorities. Bold move by the project with potential for actually raising the awareness of decision-makers.”, provided an extra impetus for the AQUACYCLE Partnership to produce further Opinion Articles.

Each of the Opinion Articles was published in Arabic, English and French, and made available for download on the project website, as illustrated in Table 6.

Table 6: Titles of Opinion Articles, month of issue and download links from project website

AQUACYCLE Opinion Papers	Issued	Download Links
The use of treated wastewater as a solution to address the impacts of climate change in Lebanon and MENA region	Nov 2020	Arabic , English , French
Democratizing spatial decision making in the water sector	Feb 2021	Arabic , English , French
WebGIS as a decision-support tool to draw up action plans for the reuse of treated wastewater	May 2021	Arabic , English , French

Over the duration of the project’s lifetime, 6 e-Newsletters were issued to subscribers, and also made available for download on the project website where they remain accessible for as long as the online platform hosted by the ENI CBC Med Programme will be maintained.



Figure 14: Cover images for news posts inviting to subscribe to AQUACYCLE’s e-Newsletters

The e-Newsletters are available for download in Arabic, English, French, Greek, and Spanish, i.e., in all of the working languages of the AQUACYCLE Partnership. The month of issue of the respective e-Newsletters and their download links are illustrated in Table 7.

Table 7: Sequence of AQUACYCLE e-Newsletters, month of issue and download links from project website

AQUACYCLE e-Newsletter	Issued	Download Links
First e-Newsletter	Feb 2020	Arabic , English , French , Greek , Spanish
Special Issue (COVID 19)	May 2020	Arabic , English , French , Greek , Spanish
Third e-Newsletter	Nov 2020	Arabic , English , French , Greek , Spanish
Fourth e-Newsletter	Jul 2021	Arabic , English , French , Greek , Spanish
Fifth e-Newsletter	Nov 2021	Arabic , English , French , Greek , Spanish
Sixth e-Newsletter	Dec 2022	Arabic , English , French , Greek , Spanish

1.9 AQUACYCLE My Autobiography

The manuscript entitled “AQUACYCLE My Autobiography”, by Eng. Dirk De Ketelaere (IRMCo), brings snippets on the progress achieved with the design, construction and operation of AQUACYCLE’s eco-innovative technology.

Along the way, AQUACYCLE meets up not only with his creators (the research teams in the AQUACYCLE Partnership) but also with water stakeholders from around the Mediterranean. AQUACYCLE maintains a log with entries that appear as chapters in the manuscript, including fictional accounts such as when AQUACYCLE went into poetry mode and called on the ENI CBC Med funded sister projects MEDISS, MENAWARA, NAWAMED and PROSIM to come to the rescue by joining forces after overhearing a water stakeholder in the Med lamenting about the ever increasing water scarcity in the wake of a changing climate, or when AQUACYCLE unwraps an early Christmas present: a 3D miniature replica.

The manuscript was published in two volumes, with a first tome issued in February 2022, with the subtitle “Anxiously waiting to make my physical appearance”, the cover and table of contents of which is illustrated in Figure 15.

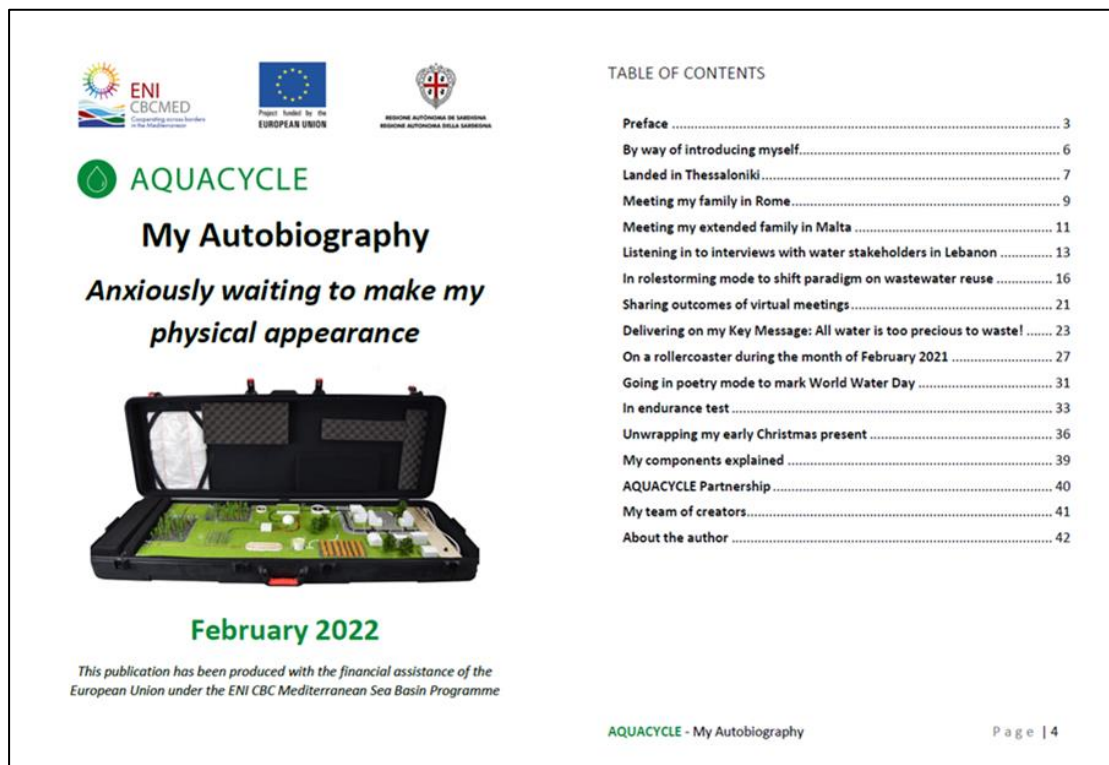


Figure 15: Cover and table of contents of first tome of AQUACYCLE My Autobiography

Its sequel was published in October 2023 with the subtitle “Exceeding expectations”, the cover and table of contents is illustrated in Figure 16.



Figure 16: Cover and table of contents of second tome of AQUACYCLE My Autobiography

1.10 AQUACYCLE channel on YouTube

Over the lifetime of the AQUACYCLE project, more than 20 video clips were uploaded to the YouTube Channel, with the customized link: https://www.youtube.com/c/AQUACYCLE_ENI_CBCMed.

The video clips can be watched also from the video section of the AQUACYCE project’s website. Table 8 brings a recapitulation of the video clips, their link on YouTube and a (shortened) description of their content.

Table 8: Brief description of video clips and their respective link on the dedicated AQUACYCLE Channel on YouTube

Video Clip	Link on YouTube	Shortened description
AQUACYCLE Launch	https://youtu.be/434AullpT5c	Watch snippets of the AQUACYCLE Launch on the occasion of the Kick-off meeting hosted by CERTH in Thessaloniki, Greece during September 30 - October 1, 2019
AQUACYCLE Photo Album of Kick-off Meeting	https://youtu.be/qmKrJLpRoXc	This clip brings a photo album of the Kick-off meeting of AQUACYCLE which took place in Thessaloniki, Greece during 30 September – 1 October 2019, hosted by the Centre for Research and Technology, Hellas (CERTH)
AQUACYCLE Photo Album of Training Event in Rome	https://youtu.be/1ZwJTBdh5ko	The 2-day training event organized in Rome by the ENI CBC Med Managing Authority on the 2nd and 3rd of October 2019 proved a truly interactive learning experience and a great opportunity for networking.
AQUACYCLE Entretiens avec des parties prenantes du secteur de l’eau et de l’assainissement au Liban	https://youtu.be/H_GG2h6b33o	Écoutez les points de vue et les attentes des parties prenantes du secteur de l’eau et de l’assainissement au Liban. Les entretiens menés par le Dr Ahmad EMoll et le Dr Mohamad Khalil de l’équipe de l’Université libanaise du partenariat AQUACYCLE mettent en lumière certaines des réalités et des besoins réels du secteur. Lisez la transcription des entretiens ici.
AQUACYCLE Interviews with stakeholders in Lebanon’s water and sanitation sector (English subtitles)	https://youtu.be/uFZTHTcWFvY	Listen in to the views and expectations of stakeholders in Lebanon’s water and sanitation sector. The interviews conducted by Dr Ahmad EMoll and Dr Mohamad Khalil from the Lebanese University team in the AQUACYCLE partnership bring into focus some of the stark realities and real needs in the sector. Read up on the transcript of the interviews.
AQUACYCLE in Rolestorming Mode	https://youtu.be/3ZmKoZxYoRg	This video clip brings snippets from the Rolestorming Session on Changing the Paradigm of Wastewater Reuse which was organized on the occasion of the AQUACYCLE Progress Meeting hosted by IRMCo Malta, which took place in Valletta, Malta during 3 to 5 February 2020.

AQUACYCLE Stakeholder Workshop in Lebanon	https://youtu.be/s6rJjPPNkfe	This clip brings snippets from the Stakeholder Workshop in Tripoli, Lebanon on the theme "Changing the Paradigm on Wastewater Reuse" organized on July 25, 2020 by the Lebanese University in the AQUACYCLE Partnership. Read up on the media coverage and testimonies of the participants on the successful event.
AQUACYCLE Stakeholder Workshop in Tunisia	https://youtu.be/Sm4cNEX_VM0	This video clip brings snippets from the Stakeholder Workshop in Tunisia on the theme "Changing the Paradigm on Wastewater Reuse" organized on 22 September 2020 by the partners CERTE and CITET. The event took place at the expertly maintained thematic gardens of the Groupement de Développement Agricole (Ecological Group for Sustainable Development), GDA Sidi Amor.
Atelier des parties prenantes d'AQUACYCLE en Tunisie (avec entretiens en arabe)	https://youtu.be/5j3qK6bOdcE	Ce clip vidéo rassemble des extraits de l'atelier des parties prenantes en Tunisie sur le thème «Changer le paradigme de la réutilisation des eaux usées» organisé le 22 septembre 2020 par les partenaires CERTE et CITET. L'événement a eu lieu dans les jardins thématiques savamment entretenus du Groupement de Développement Agricole, GDA Sidi Amor. Dans ce clip sont interviewés Mme Kitem Mensi en tant que chef de projet AQUACYCLE au nom de la CITET, ainsi que le Dr Hamadi Kallali et M. Fadhel M'Hiri en tant que chefs d'équipe au nom respectivement du CERTE et de la CITET.
AQUACYCLE shares outcomes of SWOT Analysis	https://youtu.be/Zoe1NFTQwIQ	This clip brings the outcomes of a SWOT analysis of the local governance framework with respect to wastewater treatment and reuse in Lebanon, Spain and Tunisia. The AQUACYCLE project receives funding under the ENI CBC Med programme.
AQUACYCLE partage les résultats de l'analyse FFOM	https://youtu.be/uiurvREysNhs	Ce clip présente les résultats d'une analyse FFOM (SWOT) du cadre de gouvernance locale en ce qui concerne le traitement et la réutilisation des eaux usées au Liban, en Espagne et en Tunisie. Le projet AQUACYCLE bénéficie d'un financement dans le cadre du programme IEV CTF Med.
AQUACYCLE comparte los resultados del análisis DAFO	https://youtu.be/DjWbNDRPXB0	Este videoclip muestra los resultados del análisis DAFO realizado sobre el marco de gobernanza local con respecto al tratamiento y reutilización de aguas residuales en Líbano, España y Túnez. El proyecto AQUACYCLE recibe financiación del programa ENI CBC Med.
AQUACYCLE goes in poetry mode to celebrate World Water Day 2021	https://youtu.be/n6Pw781Hyf4	This clip is based on Part 10 of AQUACYCLE - My Autobiography. To read up on AQUACYCLE's Autobiography please visit www.enicbcmed.eu/projects/aquacycle .

<p>AQUACYCLE Progress with construction of Pilot demonstration unit in Murcia Region of Spain</p>	<p>https://youtu.be/sQ5aKbEHhJM</p>	<p>This video clip shows the latest progress with the construction of two wetlands, which will receive the treated effluent of the existing anaerobic reactor at the Blanca Wastewater Treatment Plant in the Murcia Region of Spain. The third and final component of AQUACYCLE's eco-innovative wastewater treatment technology, a raceway pond reactor for solar disinfection, has also been commissioned. The pilot demonstration units will be operated and monitored by the Spanish entities ESAMUR and CIEMAT-PSA in the AQUACYCLE Partnership.</p>
<p>AQUACYCLE unwraps early Christmas present</p>	<p>https://youtu.be/pcPcbVVdLCM</p>	<p>This clip accompanies the final chapter in AQUACYCLE My Autobiography - Anxiously awaiting my physical appearance. It brings a 3D miniature presentation of AQUACYCLE's eco-innovative wastewater treatment technology, which consists of an anaerobic digester, constructed wetlands and a raceway pond reactor for solar disinfection.</p>
<p>AQUACYCLE à la télévision nationale en Tunisie</p>	<p>https://youtu.be/maRf2Vi3sMQ</p>	<p>Ce clip apporte une interview du Dr Hamadi Kallali, Chercheur au Centre de Recherche et des Technologies de l'Eau de Borj Cédria, par l'animatrice de TV1 Mme Fatma Ben Jemâa, qui a été projeté le 6 janvier 2022. Avec une part de 29,8% des 12 millions d'habitants, Wataniya 1 est la chaîne de télévision la plus regardée en Tunisie.</p>
<p>AQUACYCLE on national TV in Tunisia</p>	<p>https://youtu.be/nHlfcx-15_0</p>	<p>This clip brings an interview of Dr. Hamadi Kallali, Researcher at the Center for Research and Water Technologies in Borj Cédria, by TV1 presenter Mme Fatma Ben Jemâa, which was screened on 6 January, 2022. With a share of 29.8% of Tunisia's 12 million population, Wataniya 1 is Tunisia's most watched TV channel.</p>
<p>AQUACYCLE presenting its credentials</p>	<p>https://youtu.be/wkWz4AaX2PU</p>	<p>This clip is based on the presentation by AQUACYCLE Communication Manager, Eng. Dirk De Ketelaere (IRMCo, Malta) at the International Seminar on Social Innovation & Inclusion which took place on 26 January 2022 and was organized by the ENI CBC Med funded MEDTOWN project. (etc.)</p>
<p>AQUACYCLE meets up with Mohamed Bahri, a farmer who tills the land in North Lebanon</p>	<p>https://youtu.be/tNIMEdvs_oM</p>	<p>This clip brings an interview conducted by Tawfik al-Naboulsi and Khoder Kahil from the Lebanese University (UL) team in the AQUACYCLE Partnership. (etc.)</p>

<p>AQUACYCLE invites farmers to have their say on World Water Day 2022</p>	<p>https://youtu.be/CCZyglhCBeE</p>	<p>This clip brings snippets from interviews with farmers in Spain, Tunisia and Lebanon to mark World Water Day 2022 Groundwater – Making the Invisible Visible. (etc.)</p>
<p>AQUACYCLE Training of trainers on project's eco innovative wastewater treatment system - 1</p>	<p>https://youtu.be/q5YvsC2O1yM</p>	<p>These two video clips document the Training of trainers on AQUACYCLE's eco-innovative wastewater treatment system. The event was organized on the occasion of the project's 8th progress meeting during 22 to 24 February 2023 and took place in the Murcia Region of Spain. (etc.)</p>
<p>AQUACYCLE Training of trainers on project's eco innovative wastewater treatment system - 2</p>	<p>https://youtu.be/GZ9SVnRtPZc</p>	<p>This is the second of two video clips which document the Training of trainers on AQUACYCLE's eco-innovative wastewater treatment system. The event was organized on the occasion of the project's 8th progress meeting during 22 to 24 February 2023 and took place in the Murcia Region of Spain. (etc.)</p>
<p>AQUACYCLE Final Conference</p>	<p>https://youtu.be/vcr2dNSD86w</p>	<p>This video clip brings coverage of the AQUACYCLE Final Conference which took place at the Chamber of Commerce, Industry & Agriculture in Tripoli, Lebanon during 23 to 24 June 2023. The event, organized by the Lebanese University (LU) under the Patronage and Presence of the Minister of Environment, Dr. Nasser Yassin, was joined by over 200 participants and received extensive media coverage both at the national and local level in Lebanon. (etc.)</p>
<p>Along the water in the footsteps of the vestige of yesteryear</p>	<p>https://youtu.be/IFPCAQTQ68I</p>	<p>This video clip has been produced by the Tunisian partner, CERTE in the AQUACYCLE partnership, in the framework of the ENI CBC Med funded MEDWAYCAP project.</p>

2. Capacity Building Achievements

In this second chapter of the Capitalization Plan, the project’s efforts at capacity building are reiterated upon, starting from “Certified APOC Users”. During the lifetime of the project itself, a large number of wastewater treatment plant operators and technicians as well as water researchers and engineers partook in webinars organized by the AQUACYCLE Partnership who received training on the design, operation and maintenance of the APOC system. The latter was made possible through a Training-of-Trainers event which was organized by ESAMUR and CIEMAT-PSA in Spain during 22 and 23 February 2023. This permitted the organization of further training events in Greece, Lebanon, Spain, and Tunisia.

Furthermore, it is deemed appropriate to bring into focus the award of PhD, MSc and other tertiary degrees to students for conducting their research on one or more of the APOC components. This was greatly facilitated by the facilities available at the laboratory of Effluent Treatment and Valorization at the Water Research and Technologies Centre (CERTE) in Tunisia, where several of these students conducted their research activities under the expert guidance and supervision of Dr. Hamadi Kallali, CERTE Team Leader in the AQUACYCLE Partnership. It is especially noteworthy that all of the tertiary degrees awarded in Tunisia were presented to women researchers.

Finally, it is deemed highly appropriate to bring the spotlight once more on the women researchers in the AQUACYCLE Partnership who have been highly instrumental in achieving the successful outcomes of the project’s high-level research activities and for making the outcomes accessible to a wider public, including society at large. To this effect, the respective news posts that were carried on the project website to mark World Women Day have been revisited and included in the present Output.

Table 9: Capacity building achievements during project lifetime, recipients and quantified number of recipients

Capacity Building Achievements	Recipients	Quantified number
2.1 Certified APOC users	Wastewater treatment plant operators & technicians, water engineers and researchers	189 (exceeding the originally foreseen target of 180 Certified APOC Users)
1.2 Postgraduate research degrees awarded for research conducted in the context of AQUACYCLE	Women researchers in Tunisia	One PhD, two MSc and one Rural Engineer Diploma
1.3 Promoting the role of women in high-level research	Women researchers in AQUACYCLE Partnership	Commitment by partners in Lebanon, Spain, and Tunisia to maintain operation of pilots for at least 5 years

2.1 Certified APOC Users

A multitude of training events were organized by the AQUACYCLE Partnership in Greece, Lebanon, Spain, and Tunisia. These were largely made possible through a Training-of-Trainers' event organized by the Spanish research teams ESAMUR and CIEMAT-PSA as part of the project's 8th project progress meeting during 22 to 24 February 2023. The first day, which was hosted by ESAMUR, covered presentations on the design, operation, and maintenance of the 3 components of the APOC system. These include an anaerobic digester, one or more constructed wetlands and a solar raceway pond reactor for the disinfection of the treated effluent. The training materials employed are publicly accessible on the e-training platform of the project. The second day was devoted to a field visit to the APOC pilot demonstration unit installed at the Blanca wastewater treatment facility in the Murcia Region of Spain. On the third day, the participants visited the solar research facilities at CIEMAT-PSA in the neighbouring province of Almeria. Finally, the results of the analysis of the treated effluent from the APOC pilot demonstration unit were shared during the 8th project progress meeting which concluded the 3-day event.

A [first video clip](#) on the Training-of-Trainers' event was produced by Khoder Khalil from the Lebanese University team, while a [second video clip](#) was produced by Pedro Simon Andreu, Team Leader of ESAMUR in the AQUACYCLE Partnership.



Figure 17: Cover image of news post announcing launch of video clips on Training-of-Trainers' event

The Training of Trainers' event paved the way to organize further training events in Lebanon and Tunisia, enabling the training of an aggregate of 189 participants on the APOC technology. Preceding these training events, ESAMUR and CIEMAT-PSA organized two webinars on the APOC technology addressed to wastewater treatment plant operators and technicians in Spain. Table XX brings a recapitulation of the various training events that were organized on the APOC technology.

Table 10: Certified APOC users

Event title	Date	Country	Participants
AQUACYCLE Webinar on reuse of treated wastewater from APOC system	25/03/2022	Spain	34
Training of trainers on APOC system	22/02/2023	Spain	22
AQUACYCLE Webinar on APOC system	06/06/2023	Spain	55
AQUACYCLE Webinar - APOC User Certification & Mediterranean Alliance	28/10/2023	Lebanon	31
Training on the APOC Wastewater Treatment System	27/10/2023	Tunisia	47
Aggregate Total of Certified APOC Users			189

All participants who successfully completed the training course have been presented with the award certificate illustrated in the figure below.



Figure 18: Award presented to Certified APOC Users

2.2 Postgraduate research degrees awarded for research conducted in the context of AQUACYCLE

Several postgraduate degrees have been awarded in Tunisia during the project's lifetime based on research conducted in the context of AQUACYCLE. In fact, research was conducted on each of the components of the project's eco-innovative wastewater treatment system at the laboratory of Effluent Treatment and Valorization at the Water Research and Technologies Center (CERTE) under the expert guidance and supervision of Dr. Hamadi Kallali, CERTE Team Leader in the AQUACYCLE Partnership.

This chapter revisits the news posts which appeared on the project website, starting from the PhD degree awarded to Ms Amal Mejri for her research on the solar photo-Fenton process at the laboratory scale. As part of her doctoral thesis, she investigated the optimum liquid depth to be maintained in the raceway pond reactor with the aim to optimize the solar driven disinfection of domestic wastewater effluent.

Ms Jihene Tayahi, on her part, conducted laboratory experiments on the raceway pond reactor, investigating two Advanced Oxidation Process (AOP) reactions: the photo Fenton reaction and the Photocatalysis reaction using Titanium Dioxide (TiO₂). She was awarded with a Rural Engineer Diploma for her research.

Next in line is the news post which announced the award of an MSc degree to Ms Fatma Dridi. Her research was focused in particular on the constructed wetlands component of project's eco-innovative wastewater treatment system. For her laboratory experiments, she used the actual wastewater collected at the Bent Saidane wastewater treatment facility and through her successful employment of macrophytes was able to simulate the phytoremediation that occurs in the constructed wetlands.

Finally, an MSc Degree was awarded also to Ms Mariem Doggui for her employment of a multi-criteria evaluation in GIS environment to guide to the optimum location for a wastewater treatment facility. She applied the evaluation to the Bent Saidane region of the Zaghuan Governorate in Tunisia.

Figure 19: Cover image of news post announcing award of PhD degree to Ms Amal Mejri

Ms Amal Mejri successfully presented her PhD thesis dissertation at the National Engineering School of Sfax (ENIS) on 5 July 2021.

Her PhD thesis was carried out at the Department of Geology, University of Sfax, between September 2016 and June 2021. Her work was conducted in the framework of a joint collaboration between the Laboratory of Wastewater Treatment and valorization of Water Rejects (LTVRH) at the Water Research and Technology Centre (CERTe), Carthage University, The Department of Geology, National Engineering School of Sfax (ENIS), University of Sfax, Tunisia, and the Solar Energy Research Centre (CIESOL), at the Almeria University, Spain.

The main contribution of this PhD thesis is the application of one of the most efficient and environmentally sustainable advanced oxidation processes (AOPs), the solar photo-Fenton process, for wastewater treatment at pilot scale. Her study investigated the use of solar photo-Fenton process through scalable and low-cost Raceway Pond Reactor (RPR) to remove contaminants of emerging concern (CECs) from simulated and real urban WWTP secondary effluents at neutral pH. Among other aspects, Ms Amal Mejri’s research investigated the optimum liquid depth to be maintained in the RPR at the laboratory scale.



Figure 20: Raceway Pond Reactors of 5 cm (a) and 15 cm (b) liquid depth. Source: Ms Amal Mejri Phd Thesis

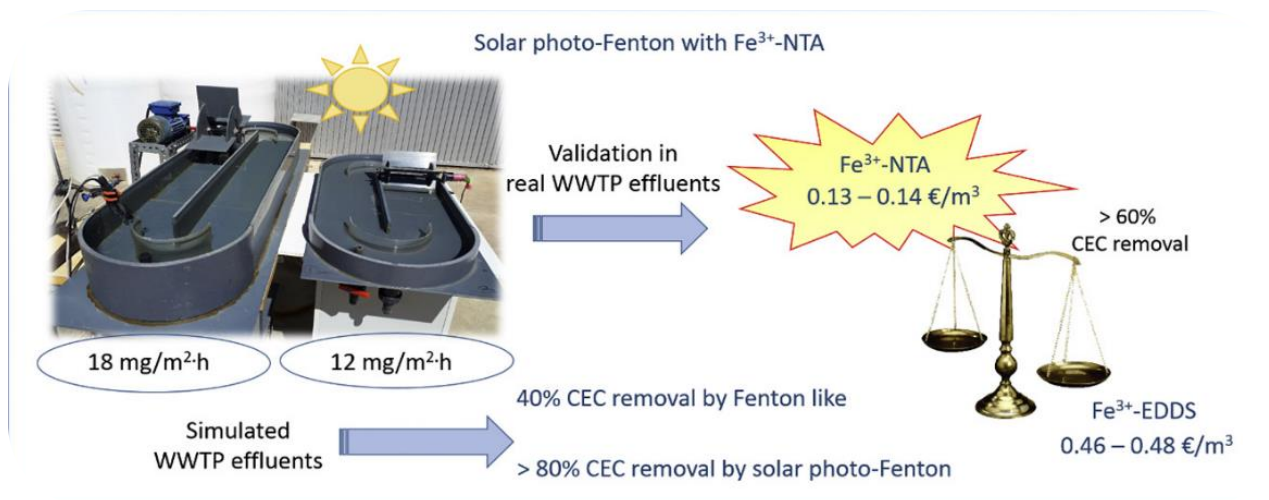


Figure 21: Graphical abstract of Fe³⁺-NTA as iron source for solar photo-Fenton at neutral pH in raceway ponds reactors. Source: Ms Amal Mejri PhD Thesis

The Raceway Pond Reactor (RPR) is the third and final component in **AQUACYCLE**'s low-cost, eco-innovative wastewater treatment (APOC) system. The APOC system consists of an Anaerobic Digester, Constructed wetlands and Photocatalytic Oxidization, i.e. solar disinfection through the Raceway Pond Reactor.

About the solar photo-Fenton process

The solar photo-Fenton (SPF) process involves the irradiation of water containing iron (as a catalyst) and H₂O₂ to promote the generation of the highly powerful oxidative and nonselective hydroxyl radical, giving rise to the removal/inactivation of organic pollutants and microorganisms. Recently, the spreading of the so-called antibiotic-resistant bacteria and their counterpart genetic elements (antibiotic-resistant genes) has become a highly concerning challenge for WW discharge and/or reuse due to the risk/impact on health for humans and the environment.

Source: María Inmaculada Polo-López, José Antonio Sánchez Pérez (2021) Perspectives of the solar photo-Fenton process against the spreading of pathogens, antibiotic-resistant bacteria and genes in the environment. Published in Current Opinion in Green and Sustainable Chemistry, Volume 27, February 2021, 100416 <https://doi.org/10.1016/j.cogsc.2020.100416>

A more detailed abstract of Ms Amal Mejri's PhD Thesis can be downloaded through [this link](#).



Figure 22: Cover image of news post announcing award of Rural Engineer Diploma to Ms Jihene Tayahi

Ms Jihene Tayahi from the Mejez El Bab Engineering School successfully presented her dissertation to obtain the **Rural Engineer Diploma** on Monday 28 June 2021.

During her stay at the Laboratory of Effluent Treatment and Valorization at the *Centre des Recherches et des Technologies des Eaux (CERTE)*, she worked on preliminary experiments linked to the adaptation of AQUACYCLE’s eco-innovative wastewater treatment system (APOC) to the Tunisian context.

The APOC system consist of an anaerobic digestion reactor, constructed wetlands and a raceway pond for solar disinfection. The APOC system brings a cost-effective treatment of domestic wastewater with minimal costs of operation and maximum environmental benefits.

As an integral part of her research, Ms Tayahi’s conducted batch experiments to simulate the reactions occurring in the raceway pond for solar disinfection. Two Advanced Oxidation Process (AOP) reactions were tested:

- The photo Fenton reaction; and
- Photocatalysis reaction using Titanium Dioxide (TiO₂)

In these experimental trials, **Ms Jihene Tayahi** used the wastewater collected from the Bent Saidane municipality which is located in the Zaghouan Governorate in Tunisia, where the APOC system is foreseen to be implemented.

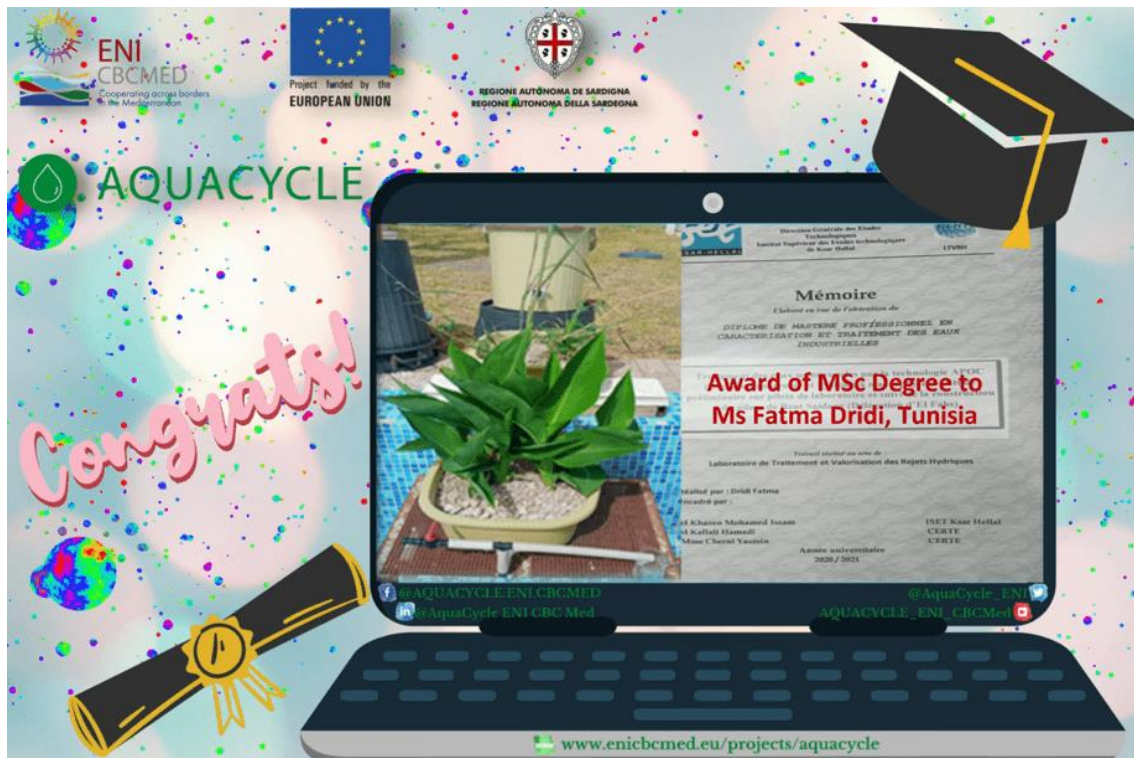


Figure 23: Cover image of news post announcing award of MSc degree to Ms Fatma Dridi

Ms **Fatma Dridi** from the Higher Institute of Technological Studies of Ksar Hellal, presented her MSc Thesis on 21 October 2021.

She conducted pilot experiments to adapt AQUACYCLE’s eco-innovative wastewater treatment system to Tunisia’s context. For this purpose, she used the actual wastewater collected at the Bent Saidane wastewater treatment facility in pilot set-ups at the laboratory of Effluent Treatment and Valorization at the Water Research and Technologies Center (**CERTE**) in the AQUACYCLE partnership. Her research was focused in particular on the constructed wetlands component, which represents the second stage of the eco-innovative APOC technology which starts from anaerobic digestion and a tertiary treatment which leads to solar disinfection in a raceway pond reactor.

In her defense on 21 October 2021 of her MSc dissertation entitled “*Rural Wastewaters treatment by the APOC technology: Preliminary study of the stages of Anaerobic Digestion and Constructed wetlands on Laboratory pilots*”, she outlined her successful employment of macrophytes to simulate the phytoremediation that occurs in the constructed wetlands.

Macrophytes are aquatic plants growing in or near water. They may be either emergent (i.e., with upright portions above the water surface), floating or submerged, as illustrated in the image below.

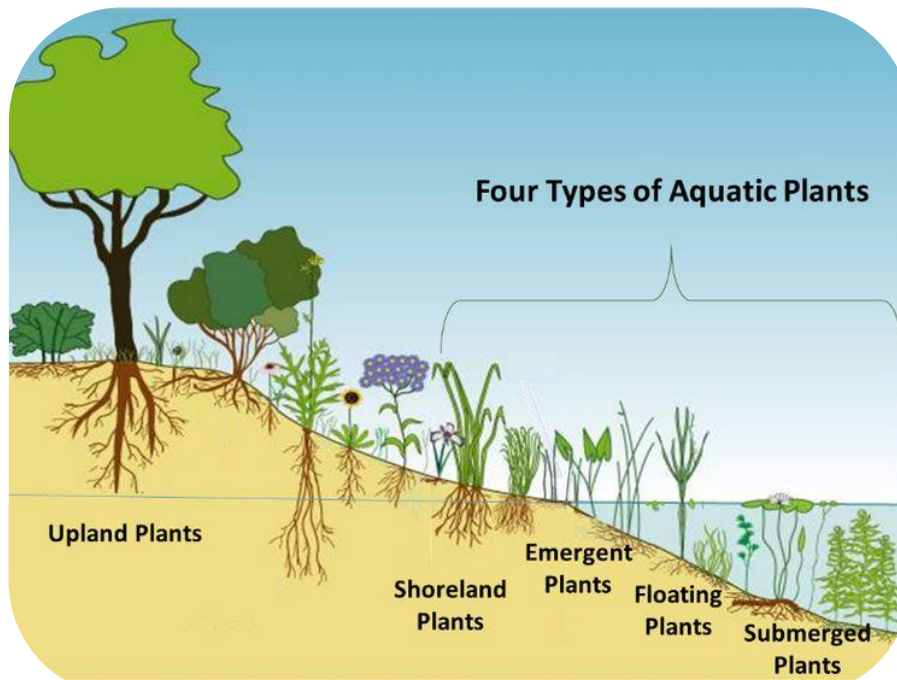


Figure 24: Classification of aquatic plants

Source:

https://www.canr.msu.edu/news/pond_plants_are_a_vital_part_of_a_balanced_aquatic_ecosystem

Phytoremediation is a plant-based approach, which involves the use of plants to extract and remove elemental pollutants or lower their concentration. This approach is typically applied to the removal of pollutants from soils and groundwater, but can also be applied to the treatment of wastewater. A schematic representation of different types of phytoremediation approaches is illustrated in the image below.

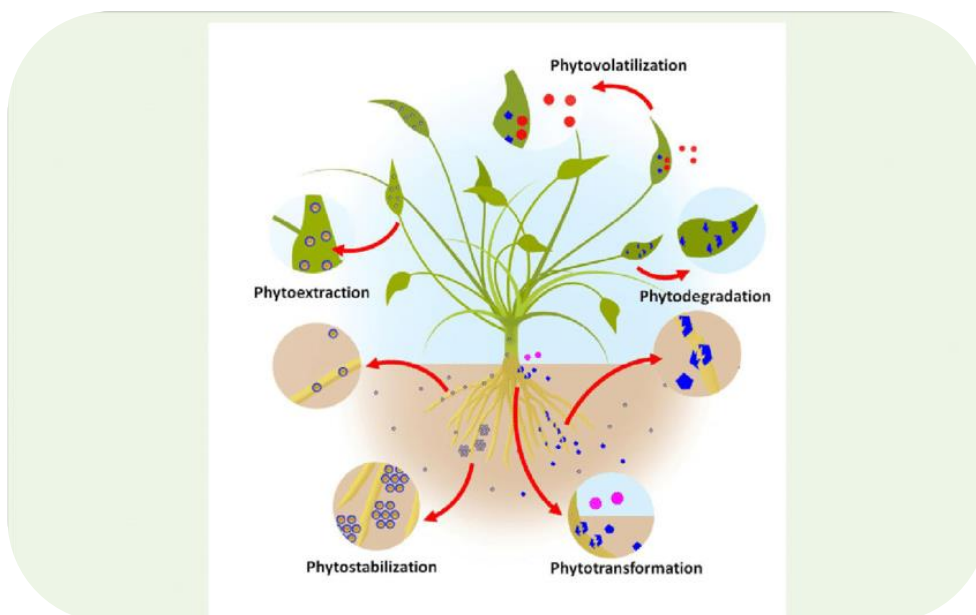


Figure 25: Classification of aquatic plants

Source:

https://www.researchgate.net/figure/Schematic-representation-of-phytoremediation-approaches_fig1_286440107 © [Shobhika Parmar](#)

Ms Fatma Dridi employed two types of macrophytes: *Phragmites australis* in a vertical flow bed and *Canna Lucifer* in a horizontal flow bed.



Figure 26: *Phragmites australis* (Common Reed)

Source: <http://cnps-yerbabuena.org/common-reed-phragmites-australis/>



Figure 27: *Canna Lucifer* (Canna Lily)

Source: <https://www.gardenia.net/plant/canna-lucifer>



Figure 28: Cover image of news post announcing award of MSc degree to Ms Mariem Doggui

Ms Mariem Doggui from the Franco-Tunisian University for Africa and the Mediterranean successfully presented her master's degree dissertation entitled “**Development of a GIS-based modeling approach for potential sites’ identification for re-using Treated wastewater for irrigation in Zaghouan governorate**”. She conducted the research at the laboratory of Treatment and Valorization of Reject Waters of the *Centre des Recherches et des Technologies des Eaux (CERTE)*.

The main objective of her research was to identify potential sites for reuse of reclaimed water for irrigation in the Bent Saidane region of the Zaghouan Governorate in Tunisia.

To guide this identification, she employed a multi-criteria evaluation coupled with a geographic information system (GIS) as a decision support tool. 12 constraints and 5 factors were determined for the selection of sites. For the purpose of analytical prioritization, a relatively simple pairwise comparison method was used. The combination of all constraints by means of the intersection operator resulted in a Boolean map in which the areas coded 0 are assumed to be unsuitable for irrigation while the remaining areas are coded 1.

Next, to identify favourable sites, the factors were normalized by means of fuzzy logic and assigned with weight coefficients.

Finally, a sensitivity analysis was applied to check the reliability of the results obtained, based on several possible scenarios using a weighted linear combination.

2.3 Promoting the role of women in high-level research

The active involvement of the multitude of women researchers in AQUACYCLE merits special mention.

The table below brings an overview of the women researchers that have been part of the research teams in AQUACYCLE and their main area of involvement.

Table 11: Women researchers involved in AQUACYCLE project

Partner	Woman researchers	Role in AQUACYCLE
CERTH	Angeliki Fotiadou	Design of wastewater treatment systems
	Eleanna Panna	Project Social Media Manager
IRMCo	Anna Spiteri	Project Communication Manager
UL	Fatima Yahya	UL Senior Researcher
CERTE	Samira Melki	CERTE Senior Researcher
	Kaouther Bargaouie	CERTE Community Manager
	Raja Jomni	CERTE Administrative Manager
	Yasmin Cherni	Joined CERTE as a post-doc (in 2020)
	Amal Mejri	Joined CERTE as PhD Candidate (in 2020)
	Mariem Doggui	Joined CERTE as an MSc Candidate (in 2020)
CITET	Khitem Mensi	CITET Communication Manager
	Anis Ghattassi	CITET Researcher
	Safa Chaabane	CITET Researcher
CIEMAT-PSA	Isabel Oller Alberola	CIEMAT-PSA Teamleader
	Inmaculada Polo López	CIEMAT-PSA Researcher
	Samira Nahim Granados	CIEMAT-PSA Researcher

To mark this achievement, news posts on the project website were issued on Women Science Day, informing about the nature, or rather their passion, for their high-level research. Further news posts were issued on World Women Day, in which the women researchers were asked to provide a brief statement sharing their viewpoints with regard to their involvement in the project, and how this involvement has been furthering their respective careers.

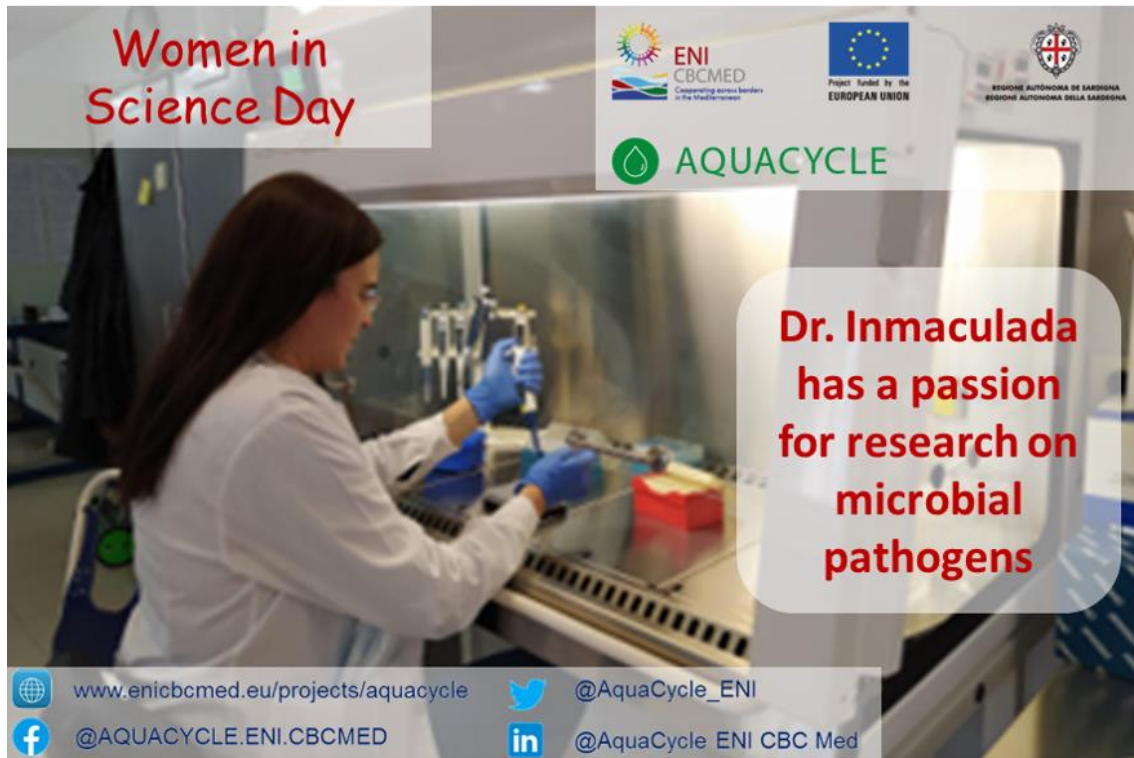


Figure 29: Meet Dr. Inmaculada who has a passion for research on microbial pathogens

AQUACYCLE is aimed at the development, implementation and testing of an eco-innovative wastewater treatment process, **APOC**, which combines commercialized technologies (**A**naerobic treatment and **C**onstructed wetlands), with novel solar water treatment technologies that are based on **P**hotocatalytic **O**xidization.

Dr. María Inmaculada Polo-López is senior researcher in the solar research group (Plataforma Solar de Almería, **CIEMAT-PSA**), in the **AQUACYCLE** Partnership. Here, she explains about her expertise in this final step of the **APOC** treatment process which is concerned with solar photocatalytic disinfection of wastewater.



“My interest in microbiology started during my high school student stage, continuing my studies with the objective of becoming a biologist. After that, I was able to obtain a doctoral scholarship at CIEMAT-PSA on water disinfection. **From the first moment, I realized that as a researcher I had the opportunity to contribute with my work and my effort to the reduction or eventually solving the impact of contaminated water on human and environmental health.** This realization, together with the fact that forming part of a wide research community with **such an important practical implication**, has been the main driving force during my currently thirteen years of research activity.”

“Microbial pathogens are, from a general point of view, those specific microorganisms with the potential to generate an infection or disease. There are many different routes through which pathogens may reach a host, and among these, water is one of the most common vehicles for the spreading of pathogens, which under certain circumstances can be fatal for both humans and animals alike. It is therefore clear that **research on the inactivation of different microbial pathogens in water is crucial to improve the safer access of water for a population**, which is directly related with the improvement of human well-being around the world, and from my personal perspective, especially important in low-income countries with high water scarcity.”

“Our capability to carry out these research activities relies on the highly equipped installations available at **CIEMAT-PSA**, which include solar pilot plants (*picture below, left*), as well as a highly equipped laboratory (*right*) for the microbial analysis of water samples”.

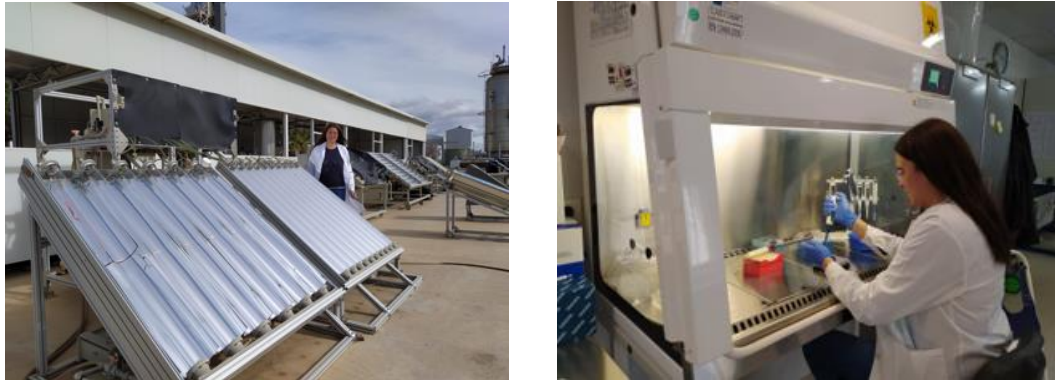


Figure 30: Solar pilot plants and highly equipped laboratory facilities for the microbial analysis of water samples at CIEMAT-PSA

Earlier this month, **Dr. Inmaculada** was an invited speaker in the **ODAK_{TR} Seminar Series**. A recording of her presentation is available on [zoom](#) and on [You Tube](#).

In this fascinating talk, entitled ‘**Antibiotic Resistant Bacteria: Occurrence and removal from Urban Wastewater**’, **Dr. Inmaculada** covers the different ways bacteria develop and acquire resistance to antibiotics, the occurrence of antibiotic-resistant bacteria (ARB), and antibiotic resistant genes (ARG) in domestic wastewater and the efficiency of conventional and non-conventional (including solar) treatment technologies for the simultaneous removal of ARB and ARG as well as antibiotics in a tertiary step of the overall treatment process.

AQUACYCLE leaps forward through active involvement of Tunisian women researchers (issued on 8 March 2022)



Figure 31: Praise of Women researchers in Tunisia marking Women's Day on 8 March 2022

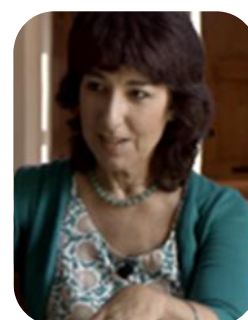
AQUACYCLE's Communication Manager, Ms Anna Spiteri elaborates on the many achievements made possible through their active involvement

To mark International Day of Women on 8 March 2022, **AQUACYCLE**'s Communication Manager, Ms **Anna Spiteri**, wishes to seize the opportunity to congratulate all the women researchers in Tunisia for their active involvement and for their valuable contributions to the **AQUACYCLE** project.

"I can proudly confirm that several of the originally foreseen ambitions in **AQUACYCLE** continue to be achieved in a highly successful manner through the active involvement of women researchers in each of the partner countries, i.e. in Greece, Lebanon, Malta and Spain. Yet, on this occasion, I wished to convey my heartfelt congratulations especially to our women research colleagues in Tunisia!"

"In fact, women researchers in Tunisia outnumber their male counterparts!"

Anna Spiteri



"Congratulations are due to Khitem Mensi, Dr. Safa Chaabane, Anis Ghattassi, Dorra Laater and Sonia Jbeli at the Tunis International Center for Environmental Technologies (**CITET**), as well as to Dr. Baha Chamam, Dr. Samira Melki, Dr. Yasmin Cherni, Amal Mejri, Fatma Dridi, Jihene Tayahi, Mariem Dougoui, Myriam Ben Said, Raja Jomni and Kaouther Bergaoui at the Water Research and Technologies Center (**CERTE**)."

“Among the above-mentioned researchers, I am most grateful to Ms Khitem Mensi, who has been steadfastly providing us with most valuable support within the realm of the communication-related activities my company is overseeing in **AQUACYCLE**.”

“In parallel and particularly during these last six months, we witnessed a series of high quality research outputs that led to the award of one PhD degree, two MSc degrees and a Rural Engineer Diploma in Tunisia. As evidenced by the links provided below, each of these awards was directly related to the improved functioning of **AQUACYCLE**’s eco-innovative wastewater treatment system. Through their efforts, we are confident that each of the three components of the treatment system, i.e. the anaerobic digester, the constructed wetlands and the solar raceway pond reactor for solar disinfection, will be fully adapted to operate at their highest efficiency under the prevailing local conditions in Tunisia. Furthermore, I am confident that this effort will bring a lasting, cost-effective solution to sustain the livelihood of rural communities in Tunisia by providing farming communities with an abundant, all-year round, and safe-for-reuse treated domestic effluent as a non-conventional source of water to meet their irrigation requirements.”

“Having had the pleasure to welcome some of my Tunisian women research colleagues in Malta in February 2019, I really look forward to the opportunity to meet in person again in the nearest future.”



Caption: Ms Khitem Mensi (right) and Baha Chamam sharing a light moment during the Second AQUACYCLE Project Progress Meeting which took place in Valletta, Malta during 3 to 5 February 2019 and was hosted by IRMCo.

Anna Spiteri is Managing Director of Integrated Resources Management Company (**IRMCo**), an environmental research company based in Malta.

ENI CBCMED

Project funded by the EUROPEAN UNION

REGIONE AUTONOMA DELLA SARDEGNA

AQUACYCLE

”

It is an important opportunity for me to join a Euro-Mediterranean project. It is my first professional experience after my thesis dissertation. I have the pleasure to be part of an enthusiastic team that undergo activities aiming to improve the environment quality. Indeed, we are advocating the use of green alternatives for wastewater treatment and its reuse in agriculture.

Dr. Yasmin Cherni

Joined the CERTE team in AQUACYCLE as a Post-Doc in 2020

International Women’s Day #IWD2022 #BreakTheBias #WoMED

Figure 32: Dr. Yasmin Cherni, who joined CERTE team in AQUACYCLE as a Post-Doc in 2020

ENI CBCMED

Project funded by the EUROPEAN UNION

REGIONE AUTONOMA DELLA SARDEGNA

AQUACYCLE

”

The fact of reusing wastewater in a context of eco-innovation with lower costs and environmental benefits is a strategic choice to preserve the water resources in the Mediterranean, especially in Tunisia. It was a great opportunity for me to have collaborated with the CERTE Tunisia Team and to bring my added value to this Euro-Mediterranean project in GIS use for decision making.

Mrs. Mariem Dougui






Joined the CERTE team in AQUACYCLE as a Master’s degree Student in 2020

Vers un Traitement et une Réutilisation Durables des Eaux Usées dans la Région Méditerranéenne

- 7 Partenaires
- 3 Unités de Démonstration
- 3 Plans d’Action
- 1 Alliance

International Women’s Day #IWD2022 #BreakTheBias #WoMED

Figure 33: Mrs. Mariem Dougui, who joined CERTE team in AQUACYCLE as an MSc student in 2020

Project funded by the EUROPEAN UNION



REGIONE AUTONOMA DI SARDEGNA
REGIONE AUTONOMA DELLA SARDEGNA

”

From my point of view, as a Tunisian younger researcher, the collaboration with a Spanish team from the University of Almeria, during my doctoral studies, was very interesting and fruitful. During my successive research stays at the Researcher Center on Solar Energy (CIESOL), Therefore, this successful experience gave me the opportunity to develop a lot of academic skills in the field of Wastewater Treatment, and environmental background. Indeed, this fruitful collaboration has added a lot to my research course and makes it easier for me to work with several people with different cultures.

Dr. Amal Mejri

Joined the CERTE team in AQUACYCLE as a PhD Candidate in 2020

International Women's Day #IWD2022 #BreakTheBias #WoMED




Figure 34: Dr. Amal Mejri, who joined CERTE team in AQUACYCLE as a PhD Candidate in 2020







Project funded by the EUROPEAN UNION

REGIONE AUTONOMA DI SARDEGNA
REGIONE AUTONOMA DELLA SARDEGNA

”

It is a great opportunity for me to be part of the AQUACYCLE project funded by the EU that promotes a sustainable water circular economy and facilitates rural WASH as well as women empowerment by implementing APOC Systems as eco-innovative wastewater treatment and reuse technology. There is an urgent need for Tunisia to step path towards women's involvement in sustainable water management, environmental and social development.

Dr. Safa Chaabane

Joined the CITET team in AQUACYCLE as a Researcher in Wastewater Treatment and Reuse in 2020




International Women's Day #IWD2022 #BreakTheBias #WoMED



Figure 35: Dr. Safa Chaabane, who joined CERTE team in AQUACYCLE as a Researcher in 2020

AQUACYCLE

It is a great opportunity for me to be part of the AQUACYCLE project funded by the EU. It has been a pleasure to be part of such an interesting Euro-Mediterranean project. I'm excited to continue in this journey and looking forward to the challenges ahead to advance the use of PGIS in Tunisia.

Dr. Samira Melki
 Joined the CERTE team in AQUACYCLE as a Senior Researcher in 2021

International Women's Day #IWD2022 #BreakTheBias #WoMED

Figure 36: Dr. Samira Melki, who joined CERTE team in AQUACYCLE as a Senior Researcher in 2021

AQUACYCLE

It is a great opportunity for me to be part of the AQUACYCLE EU funded project. It has been a pleasure to be part of such an interesting Euro-Mediterranean project. Therefore, this successful experience gave me the opportunity to develop and learn a lot of administrative and financial tasks.

Mrs. Raja Jomni
 Joined the CERTE team in AQUACYCLE as an Administrative Manager in 2019

International Women's Day #IWD2022 #BreakTheBias #WoMED

Figure 37: Mrs. Raja Jomni, who joined CERTE team in AQUACYCLE as an Administrative Manager in 2019

ENI CBCMED

Project funded by the EUROPEAN UNION

REGIONE AUTONOMA DI SARDEGNA
REGIONE AUTONOMA DELLA SARDEGNA

AQUACYCLE

”

The AQUACYCLE Communication team is special in so many ways! The Community team is spread out all around the world, and while we rarely get to be all together around one project, we’ve built incredibly strong relationships based on trust and communication. We all come from very different professional backgrounds, which is one of our biggest strengths. It makes us creative, flexible, and efficient. We took the pandemic opportunity to explore new formats, new content, and delivered incredibly successful events. In fact, our virtual events have been so successful that we may continue to organize them moving forward!

Mrs. Kaouther Bargaoui
Joined the CERTE team in AQUACYCLE as a Community Manager in 2019

International Women’s Day #IWD2022 #BreakTheBias #WoMED

Figure 38: Mrs. Kaouther Bargaoui, who joined CERTE team in AQUACYCLE as a Community Manager in 2019

3. AQUACYCLE Key Achievements

In this final chapter, the project achievements are assessed against the expected results at the ENI CBC Med Programme level and then also against the originally foreseen project outcomes.

The AQUACYCLE project was designed to meet three of the expected results of the ENI CBC Med Programme, as illustrated in Table 12, and described in more detail below:

Expected Result 1: Research and development of a low-cost technology for the (re)use of non-conventional water resources: the eco-innovative APOC wastewater treatment system for the treatment of domestic effluent has proved itself a low-cost technology, ideally suited for application in small- to medium-sized rural communities around the Mediterranean. Its potential to also produce biogas and fertilizer as well as to serve as a habit of biodiversity (through its constructed wetland) render the technology as a textbook example of the Circular Economy.

Expected Result 2: Outreach activities in support of promoting the use of non-conventional water resources: the AQUACYCLE Partnership organized a multitude of stakeholder engagement and other outreach activities. These included activities addressed to building synergies with ENI CBC Med funded ‘sister’ projects, Horizon 2020, Life and other EU funded projects, outreach activities with junior high school students, participation in international fora to explore investment opportunities, and more. Jointly, the number of outreach activities during the AQUACYCLE project lifetime reached 21, i.e. exceeding the target value set for the programme as whole.

Expected Result 3: Drawing up of local actions plan for the reuse of non-conventional water resources with a target volume of 300000 m³ of reuse per annum: the local action plans in Lebanon and Tunisia each target a volume of 300000 m³ of reuse per annum. These have been drawn up through the intermediation of an online Irrigation Support Tool. The methodology and approach developed has demonstrated that these action plan can duly take into consideration areas for irrigation with treated effluent as suggested by the local communities in Lebanon and Tunisia through the use of Participatory GIS. In Spain, the action plan for the reuse of treated effluent amounts to 12.5 million m³ per annum, which reflects the actual reuse of treated effluent from the municipal wastewater treatment facility in Blanca in the Murcia Region of Spain, which is among the highest levels of reuse of treated effluent in Europe. Jointly the action plans therefore reach the volume of 13.1 million m³ of reuse per annum, thereby exceeding on the programme target value by a huge margin.

Table 12: AQUACYCLE achievements in relation to targets set by ENI CBC Med Programme

Programme expected results	Programme target value	AQUACYCLE target value	Value achieved in AQUACYCLE
4.1.2D – Research and development of a low-cost technology for the (re)use of non-conventional water resources	2	1	1
4.1.2E – Organization of outreach activities in support of promoting the use of non-conventional water resources	20	10	21
4.1.2.F – Drawing up of local actions plan for the reuse of non-conventional water resources with a target volume of 300000 m³ of reuse per annum	1,800,000	900,000	13,100,000

A further assessment is made of the achievements of the AQUACYCLE project in relation to the quantified targets of the originally foreseen project outputs. The latter are described in more detail below together with a recapitulation of the achievements illustrated in Table 13. Several of these outputs contributed to reach the aggregate of 21 outreach activities reported in Table 12 (the breakdown of the number of outreach activities is shown *in italics* next to the relevant project outputs listed below).

- 1) **SWOT Analysis of local Governance Framework:** 19 high-level water stakeholders were interviewed in Lebanon, Spain, and Tunisia as well as in Algeria to collect their views and perceptions on the challenges and barriers to the uptake of non-conventional water resources, exceeding the target of 15 interviews (*counted as 1 outreach activity*);
- 2) **Prototype PGIS based Decision Support tool:** The project's prototype PGIS based Decision Support tool has been tested and validated in Lebanon, Spain, and Tunisia;
- 3) **Stakeholders' expectations and training needs:** Stakeholders' expectations and training needs were collected through the organization of the First Series of Stakeholder Workshops in Lebanon, Spain, and Tunisia, thus achieving the target value of 3 events as originally foreseen (*counted as 3 outreach activities*);
- 4) **Online PGIS environment for participatory planning:** PGIS Landing Pages were set up for each of the foreseen pilot demonstration sites in Lebanon, Spain, and Tunisia. Intentionally, these were given the same 'look' and 'feel', both in terms of the information layers these contain and the colours of the legends, so as to facilitate a cross-border exchange and interpretation of the outcomes. Furthermore, each of the PGIS Landing Pages include a layer depicting 'Places of Interest', which further facilitated the ease of navigation for PGIS users.
- 5) **APOC technical guide:** the project produced a comprehensive technical guide, encompassing details on how to design, operate and maintain each of the components of the APOC wastewater treatment system;
- 6) **Demonstration Units:** By the end of the project lifetime, the demonstration unit in Spain had been in active operation for over one year, while the demonstration units in Lebanon and Tunisia saw the completion of the construction works just before the end of the project lifetime;
- 7) **e-toolbox:** this was implemented as an e-training platform on the design, construction and maintenance of each of the components of the APOC wastewater treatment system. Moreover, its functionality offers a forum for the exchange of ideas, viewpoints etc. of users around the world;
- 8) **Spatial analysis of APOC opportunities in GIS environment:** the online Irrigation Support Tool permits a GIS-based analysis - anywhere in the world - to arrive at optimum action plans for the reuse of treated effluent;
- 9) **Active PGIS users:** Organized as part of the Second Series of Stakeholder Workshops, an aggregate of 37 representatives of local society, including farmers, took part in Lebanon and in Tunisia to make an active use of the PGIS Landing Pages to bring their suggestions for the reuse of treated effluent into view, by delineating the areas they wished to see irrigated with treated wastewater and detailing the purpose of the irrigation (type of crop, landscaping, etc.) (*counted as 2 outreach activities*);
- 10) **Cost-benefit and performance analysis of pilot units:** following the monitoring and assessment of the pilot demonstration unit at the Blanca wastewater treatment over a period of over one year, it was ascertained that the APOC treatment system is more cost-effective as compared to conventional treatment systems. Moreover, it was ascertained the treated domestic wastewater meets the most recently introduced EC regulation on the minimum requirements for reuse of water.

- 11) Certified APOC users:** an aggregate of 189 participants were awarded with a Certificate having successfully completed training on the APOC wastewater treatment system. This number was reached following the organization of a Training of Trainers event in Spain; the organization of 2 webinars addressed to wastewater treatment operators and technicians in Spain, a webinar in Lebanon and a physical training event in Tunisia (see Table 10 for details) *(counted as 5 outreach activities)*;
- 12) Local action and investment plans:** Local action plans for Lebanon and Tunisia were drawn up in preparation for the third series of workshops, during which participants provided their insights also on possible investment routes *(counted as 2 outreach activities)*; The event in Spain was replaced by a webinar in which key invited experts shared insights also on the further research needs to comply with the new EU Regulation on the Minimum Requirements for Water Reuse, and on the future action and investment plans for the construction of wastewater treatment facilities in the South-East of Spain *(this webinar is already accounted for as an outreach activity with the previous project output, Certified APOC users)*;
- 13) Portfolio of outreach activities:** An impressive aggregate of 21 of outreach activities have been organized by the AQUACYCLE Partnership to support and promote the reuse of non-conventional water resources;
- 14) MedAPOC Charter:** A semi-final version of the MedAPOC Charter was issued in March 2023 to mark World Water Day, while the final version was issued on the occasion of the project's Final Conference in June 2023 *(counted as 1 outreach activity)*; and
- 15) Mediterranean Wastewater Reuse Community:** By signing up to the MedAPOC Charter, the signatories become members of the project's Mediterranean Wastewater Reuse Community. Over 150 signatories from around the Region were collected online, while over 200 participants joined the project's Final Conference. Thus, during the lifetime of the project, AQUACYCLE's Mediterranean Wastewater Reuse Alliance has been joined by over 350 persons.

A further explanation is merited to justify the aggregate of 21 outreach activities. While the above informs about the interviews with high-level stakeholder *(counted as 1)*, the organization of the First Series of Stakeholder Workshops in Lebanon, Spain and Tunisia *(counted as 3)*, the PGIS workshops in Lebanon and in Tunisia *(counted as 2)*, the training events on the APOC technology *(counted as 5)*, the discussion on the local action and investments plans in Lebanon and in Tunisia on the occasion of the Third Series of Stakeholder Workshops *(counted as 2)*, and the Final Conference *(counted as 1)*, a total of 14 outreach activities is accounted for. The complement of an additional 7 outreach activities is reached by including: the presentations on AQUACYCLE to high-school students in Greece and in Spain *(counted as 2)*, the organization of national seminars on the topic of water and sanitation in Lebanon *(counted as 2)*, the joint event organized with AQUACYCLE's 'sister' ENI CBC Med funded projects on the thematic of 'water efficiency' *(counted as 1)*, the participation of AQUACYCLE at the Ecological Construction and Innovation Days' Fair in Tunisia and the setting up of an AQUACYCLE booth at the Water-Energy-Food-Environment Nexus Innovation Week, an online brokerage event *(counted as 2)*.

Table 13: AQUACYCLE achievements in relation to the originally foreseen quantified target outputs

Project outputs, as measured through Key performance indicators (in italics)	Programme target values	AQUACYCLE target value	Achieved value in AQUACYCLE
<i>SWOT Analysis of local Governance Framework: Interviews with high-level water stakeholders</i>	20	15	19
<i>Prototype PGIS based Decision Support tool: Irrigation Support Tool, PGIS based</i>	4	1	1
<i>Stakeholders' expectations and training needs: Workshops in Lebanon, Spain and Tunisia</i>	12	3	3
<i>Online PGIS environment for participatory planning: PGIS Landing Pages</i>	4	1	1
<i>APOC technical guide: APOC technical guide manuscript</i>	6	1	1
<i>Demonstration Units: Pilot demo units installed in Lebanon, Spain and Tunisia</i>	6	3	3
<i>e-toolbox: Online training platform on design, operation and maintenance of APOC system</i>	4	1	1
<i>Spatial analysis of APOC opportunities in GIS environment: Report of Spatial analysis</i>	4	1	1
<i>Active PGIS users: participants in Lebanon and Tunisia who joined PGIS workshop</i>	20	30	37
<i>Cost-benefit and performance analysis of pilot units: Report on Cost-benefit and performance</i>	12	1	1
<i>Certified APOC users: number of persons trained on APOC technology</i>	320	180	189
<i>Local action and investment plans: Achieved for case studies in Lebanon, Spain and Tunisia</i>	12	3	3
<i>Portfolio of outreach activities: One portfolio with 21 distinct outreach activities</i>	4	1	1
<i>MedAPOC Charter Final version of Charter</i>	4	1	1
<i>Mediterranean Wastewater Reuse Community One alliance, launched at Final Conference</i>	4	1	1