Grant Agreement No.: 689817

Project acronym: INNOQUA

Project title: Innovative Ecological on-site Sanitation System for Water and Resource Saving

Innovation Action

Topic: Water-1b-2015: Water Innovation: Boosting its value for Europe – Demonstration/pilot activities

Starting date of project: 1st of June 2016

Duration: 48 months

D4.2 – Demonstrator

Organisation name of lead contractor for this deliverable: UDG		
Version–Draft-01	Due Date	30/11/2017
	Submission Date	30/11/2019
	Authors	Luca Sbardella (UDG) Victoria Salvadó (UDG) Teresa Serra (UDG)

Dissemination Level		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

Table of Tables

Table of Figures

1 Introduction

The aim of the INNOQUA Project is to progress, towards commercialisation, the development of a fully ecological sanitation solution that integrates individual low cost, sustainable and biologically based technologies. The INNOQUA Project commenced in June 2016 (M01) and this report, Deliverable 4.2 (D4.2), visually describes the Prototypes for the field testing in the controlled environments installed and operated at the facilities of the University of Girona and the National University of Ireland Galway.

1.1 Work Package 4 Objectives

The objective of WP4 Prototypes in Controlled Environment Testing is to move from design to first version integrated prototypes, tested in semi-controlled environments. As such, WP4 will conduct prototyping and small-scale field testing to verify in a coordinated way, efficiency, water output characteristics and subsequently refine any core system components.
Specifically, WP4 objectives are listed in the DoA as follows:

- To coordinate integrated project-level prototyping.
- To establish the range of environmental conditions to be tested (light, temperature),
- To establish guidelines for testing the prototypes
- To define and coordinate any necessary system refinement
- To confirm performance of each process unit stage treating wastewater with characteristics representative of the intended applications
- To define and exercise consortium supply chains and what post project exploitations could look like.
- To conduct small-scale field testing, document results, lessons learned and best practices.

1.2 The Role of Deliverable D4.2

The goal of D4.2 is to provide a comprehensive graphic report referring to prototyping set-up, integration and field testing activities, in the framework of WP4.

1.3 Relationship with other Activities in the Project

The tasks carried out during WP4 have a critical role in the project development marking the transition in the project to physical testing and modelling with the prototype unit installation at the NUI Galway and UDG controlled environment test facilities in Galway, Ireland and Girona, Spain.

Figure 1: Relationship of Deliverable D4.2 to Project Activities shows the interdependencies and relationships between project work packages as they relate to WP4 and Deliverable D4.2 (link 3, 4, 5 and 8).

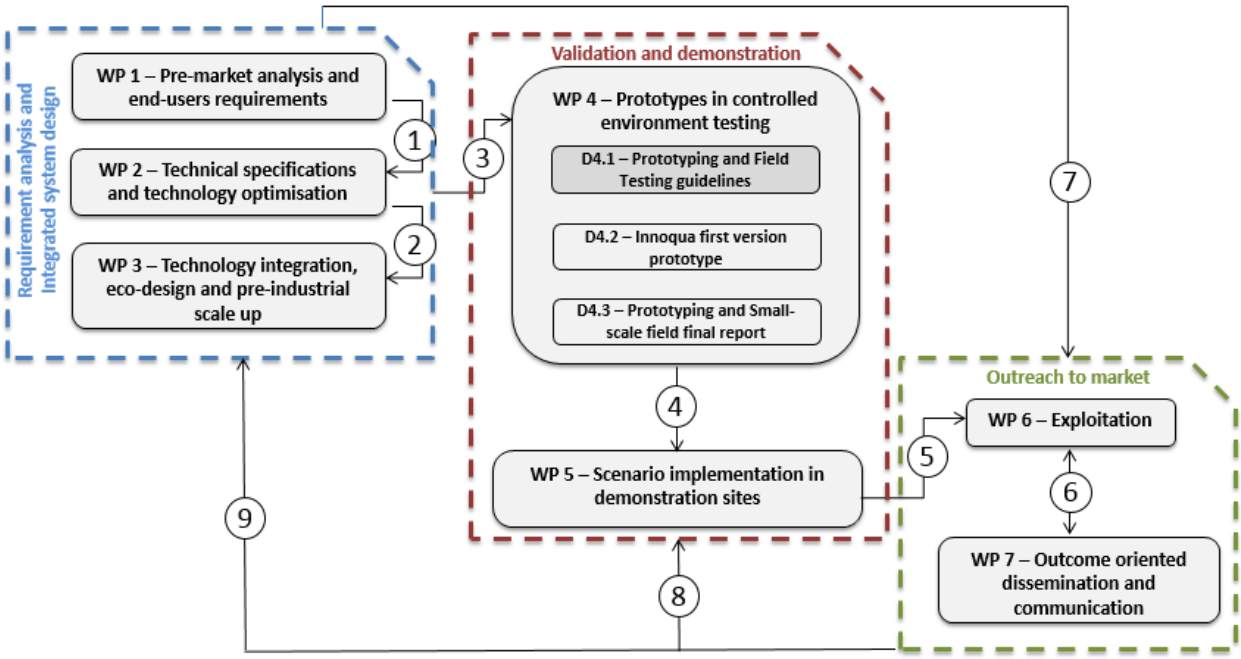

Figure 1: Relationship of Deliverable D4.2 to Project Activities

WP4 builds on the scenario development and pre-market analysis of WP1 and design and integration guidelines from WP3. It provides direction and standardisation for application at the large-scale demonstrations in WP5. WP4 also provides the first physical output of the project making it a key generator of dissemination material.

1.4 Document Outline

In particular, this document provides visual information regarding the integrated INNOQUA Technology in the following Chapters;

- Chapter 1: Site Scale integrated INNOQUA system at NUI Galway, Tuam
- Chapter 2: Site Scale integrated INNOQUA system at UDG, Quart

2 Site Scale INNOQUA System at NUI Galway, Tuam

As foreseen in the WP4, in order to carry out the prototypes validation and demonstration, the 10 P.E. site scale Lumbrifilter prototype was firstly installed at the NUI Galway WRF at Tuam, Co Galway. Tuam is located in the county of Galway 35 km north of Galway city. The town has a population of 8,500 people and is the site of the NUI Galway Water Research Facility (WRF), next to the Tuam Wastewater Treatment Plant. The INNOQUA system at this pilot site is treating municipal wastewater from the town. The wastewater also comprises stormwater during rainfall periods. The INNOQUA system installed is designed for a 10 population equivalent and would be able to treat 1.5 m^3/day. The treated water would be suitable for discharge to surface water and some re-use applications.

Figure 2: Overview of the NUI Galway pilot site

Table 1: Key parameters of NUIG pilot site

DESIGN CAPACITY:	SOURCE OF WASTEWATER	TECHNOLOGY	PARTNER RESPONSIBLE	DIMENSION OF THE SYSTEM
1.5m^3/day	Municipal	Lumbrifilter + Daphniafilter + UV	NUIG	Lumbrifilter: 3 m^3 Daphniafilter: 1 m^3

Table 2: Timeline of the NUIG pilot site preparatory and installations works

Crt. No.	Action	Details
1.	Specific technical design pilot site layout	December 2016 (M08)
2.	Tanks design validation	July 2017 (M15)
3.	Tanks manufacturing	November 2017 (M19)
4.	LF Tanks delivery	May 2018 (M25)
5.	LF start-up	July 2018 (M27)
6.	LF testing	August – November 2018 (M28-M31)
7.	DF tank delivery	March 2019 (M35)
8.	DF start-up	April 2019 (M36)
9.	UV start-up	April 2019 (M36)
10.	Integrated INNOQUA system start-up	June 2019 (M38)

Table 3: Description of the NUIG pilot site

ALTITUDE:	YEARLY AVERAGE TEMPERATURE °C:	MAX/MIN TEMPERATURE °C	ANNUAL RAINFALL
50 mm	12 °C	+ 18°C / +3°C	1400 mm

Table 4: Influent quality and treatment targets at the NUIG pilot site

Quality Parameter	Influent quality	Discharge limits *
	mg/L	
TSS	69.4 ± 28.9	35
COD	605 ± 285.9	125
BOD	230 ± 136	25
$N\text{-}NH4^{+}$	29.7 ± 5.4	
Total N	72 ± 23	
Total P	9.6	

* Urban wastewater treatment directive
Standard deviation values refer to n°= 8 samples

Figure 1 shows the layout of the pilot installations: the raw municipal influent wastewater is primarily settled, then is pumped at the top of the Lumbrifilter and passes throughout the entire filter bed, reaching then the collection pump station 1 from where it is pumped inside the Daphniafilter. The outlet overflowing from the Daphniafilter is then either discharged or further treated by means of UV treatment.

Figure 3: Scheme layout of the integrated INNOQUA system at NUI Galway pilot site

2.1 The lumbrifilter

The 10 P.E. site scale Lumbrifilter prototype arrived at the NUI Galway WRF at Tuam, Co Galway in M25. Following setup and addition of the internal layers, initial biomass establishment commenced in M27. According to the results of the tests carried out at laboratory scale from NUI Galway (Deliverable D4.3), the active woodchip layer was reduced to a 1m height and and 15,000 earthworms of type *Eisenia Fetida* were introduced to the tank in M28. From M28 to M31 several different operating conditions have been tested with the goal of establishing the response of the Lumbrifilter under different organic and hydraulic load conditions.

Figure 4: The 10 P.E. Lumbrifilter installed at the NUI Galway pilot site

The 10 P.E. site scale Lumbrifilter prototype arrived at the NUI Galway WRF at Tuam, Co Galway in M25. Following setup and addition of the internal layers, initial biomass establishment commenced in M27. According to the results of the tests carried out at laboratory scale from NUI Galway (Deliverable D4.3), the active woodchip layer was reduced to a 1m height and and 15,000 earthworms of type *Eisenia Fetida* were introduced to the tank in M28. From M28 to M31 several different operating conditions have been tested with the goal of establishing the response of the Lumbrifilter under different organic and hydraulic load conditions.

2.2 The daphniafilter

After few months of operation of the Lumbrifilter, also the Daphniafilter, previously characterized at the UDG demo site facilities, was installed. The installation of the pilot and the inoculation of Daphnias (Figure 5), were realized respectively during M35 and M36. At the beginning the two systems were operated in parallel, without connecting them. Whereas, from M38 on, the outlet of the Lumbrifilter has been connected to the inlet of the Daphniafilter in order to operate the integrated INNOQUA system.

Figure 5: The 10 P.E. Daphniafilter connected to the Lumbrifilter, assembling the integrated INNOQUA system at the NUI Galway pilot site

Figure 6: Inoculation of Daphnia inside the Daphniafilter at NUI Galway pilot site

Figure 7: Top view if the integrated INNOQUA system at NUI Galway pilot site

2.3 The UV system

After having established a normal day to day operation of the Lumbrifilter and Daphniafilter under different loads, a third technology has been added to the system in order to be able to further improve the quality of the treated water; mostly for reuse applications. The UV system was installed during M38.

Figure 8: Outside view of the UV system at NUI Galway pilot site

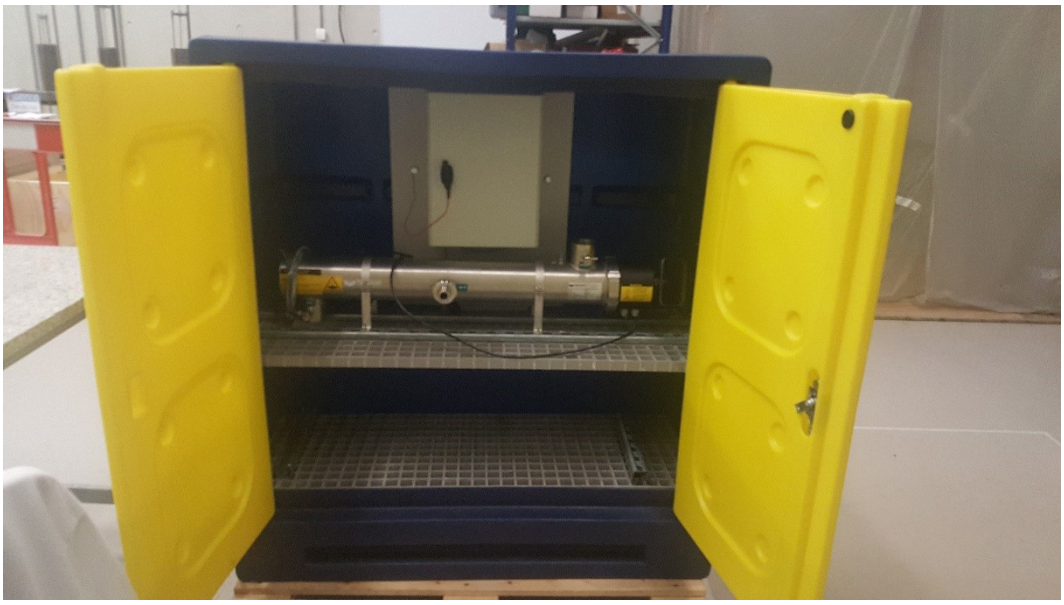

Figure 9: Inside view of the UV system at NUI Galway pilot site

3 Site Scale INNOQUA System at UDG site, Quart

As foreseen in the WP4, in order to carry out the prototypes validation and demonstration, two 10 P.E. site scale Daphniafilter prototypes were firstly installed at the WWTP of Quart, in the southeast part of Spain close to the city of Girona, in the Catalonia region. The INNOQUA system treats the raw wastewater from the villages of Quart. This pilot site is operated aiming at testing different experimental conditions for research and validation purposes; thus is working in parallel to the conventional WWTP. The INNOQUA system installed is designed for 10 population equivalent and would be able to treat 1.5 m^3/day. The treated water would be suitable for discharge to surface water and some re-use applications.

Figure 10: Integrated INNOQUA system and the BSP pilot at UDG pilot site

Table 5: Key parameters of UDG pilot site

DESIGN CAPACITY:	SOURCE OF WASTEWATER	TECHNOLOGY	PARTNER RESPONSIBLE	DIMENSION OF THE SYSTEM
1.5m^3/day	Municipal	Lumbrifilter + Daphniafilter + UV + BSP	UDG	2 Lumbrifilter: 1.5 m^3 each Daphniafilter: 1 m^3

Table 6: Timeline of the UDG pilot site preparatory and installations works

Crt. No.	Action	Details
1.	Specific technical design pilot site layout	December 2016 (M08)
2.	Tanks design validation	July 2017 (M15)
3.	Tanks manufacturing	November 2017 (M19)
4.	DF Tanks delivery	March 2018 (M23)
5.	LF Tanks delivery	February 2019 (M34)
6.	BSP Tank delivery	October 2018 (M30)
7.	DF start-up	April 2018 (M24)
8.	DF testing	April 2018– June 2019 (M24-M38)
9.	LF start-up	April 2019 (M36)
10.	BSP start-up	August 2019 (M40)
11.	Integrated INNOQUA system start-up	June 2019 (M38)

12.	LF improvement	June – October 2019 (M38 – M42)

Table 7: Description of the UDG pilot site

ALTITUDE:	YEARLY AVERAGE TEMPERATURE °C:	MAX/MIN TEMPERATURE °C	ANNUAL RAINFALL
76 m	23 °C	+ 31°C / +2°C	749 mm

Table 8: Influent quality and treatment targets at the UDG pilot site

Quality Parameter	Influent quality	Discharge limits **
	mg/L	
TSS	396±258	35
COD	632±262	125
BOD	392±262	25
N-NH4^{+}	40±12	
Total P	5±2	

** Urban wastewater treatment directive
*Standard deviation values refer to n°=24 samples

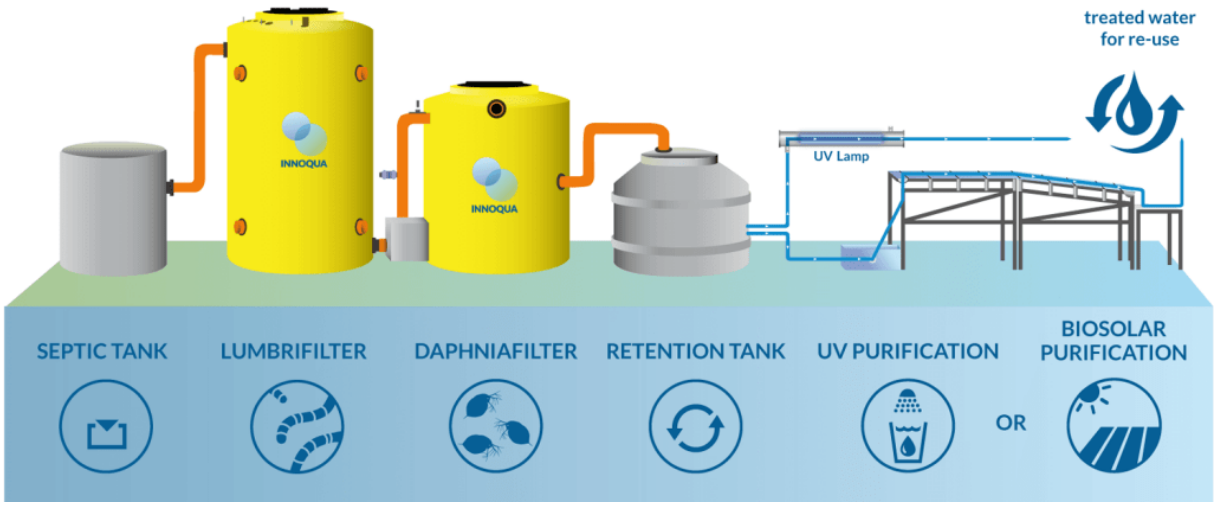

Figure 11: Scheme layout of the integrated INNOQUA system at UDG pilot site

3.1 The daphniafilter

During M23 two 10 P.E. site scale Daphniafilter prototypes were firstly installed at the WWTP of Quart (Figure 10). Following the setup, secondary effluent wastewater was circulated

inside the reactor in order to initiate the initial biomass establishment in M24. Therefore, biofilm development and growing was sought at the inner walls of the reactor, as well as on top of the plates appositely inserted inside the reactor. After this initial biofilm establishment, Daphnias were introduced in the tank, with a concentration of 0.5 Daphnias/L, and then the pilot plant was started at 100% nominal load (1500 L·d-1). One prototype was thermally isolated, while the other one was operating without insulation in order to assess the effect of the temperature. The effect of the temperature has been evaluated during M24 and M31, and eventually it has been noticed that there was no significant difference between the isolated and non-isolated reactors, i.e the water temperature in the Daphniafilter was basically determined by the temperature of the water from the previous treatment. Therefore, the evaluation of the Daphniafilter prototype continued only with one reactor, while the second one was shipped to Galway in order to be connected with the Lumbrifilter.

Figure 12: Top view and front view of the two Daphniafilters operated in parallel at UDG pilot site

In order to monitor the internal functioning of the DF, the latter was equipped with DO, turbidity, and temperature probes (Figure 11). Among the most important parameters to ensure a correct operation of the Daphniafilter, the dissolved oxygen (DO) concentration is key to provide oxygen for daphnia's respiration. With this regard, during M24 – M27 low values of DO inside the reactors were observed and reported in D4.3. Therefore, aiming at solving this issue, a technical adjustment has been realized at the influent of the Daphniafilter; the modification was done in order to aerate the influent wastewater according to the Venturi principle (Figure 12). This modification was performed in the tube of the inlet to the Daphniafilter. The modification resulted in higher DO values, as reported in the previous D4.3, improving therefore the performance of the Daphniafilter. Starting from M24, both the reactors were equipped with the monitoring and control units (Figure 14), providing online data with respect the oxygen, pH, temperature and turbidity.

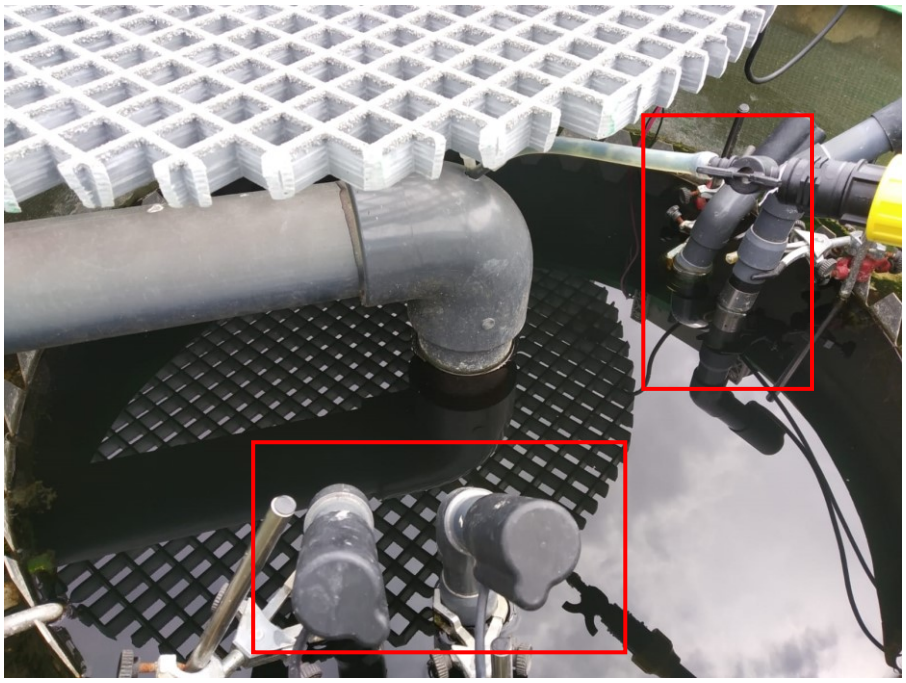

Figure 13: DO, turbidity and temperature probes.

Figure 14: Inside view of the 10 P.E. Daphniafilter, after the modification with the Venturi tube (red rectangle)

Figure 15: Daphnias inside the Daphniafilter at UDG pilot site

Figure 16: Monitoring and control unit installed on the Daphniafilter at the UDG pilot site

3.2 The lumbrifilter

Two 5 P.E. Lumbrifilter tanks were delivered at the UDG demo site in M35, and were filled with both the inert materials (woodchips, gravels and pozzolana) and 15,000 earthworms of type *Eisenia Fetida* . This technology was primary installed, operated and optimized by NUI Galway, and then set up in the UDG pilot site, taking into account the experimental results obtained during the optimization process (D4.3). The first two months of operation of the Lumbrifilter technology were necessary to evaluate the system and reach an effluent quality suitable with the following connection with the Daphniafilter. Indeed as it has been observed during preliminary laboratory experiments (D2.3), prior to connect the Lumbrifilter with the Daphniafilter, COD, TSS and $N\text{-}NH_4^+$ have to be checked and ensured to be lower than the threshold values critical for the survival of Daphnia. Hence, at the beginning of M38, when COD, TSS and $N\text{-}NH_4^+$ removals allowed to achieve concentration lower than 60 mg/L, 20 mg/L and 5 mg/L, respectively, the two systems were connected.

3.3 The UV system

Reproducing the same Full Experimental Setup as it was in the case of Galway demo site, also at the UDG demo site, a UV lamp was installed in order to upgrade the integrated INNOQUA system effluent quality. A previous set up of the UV system was carried out during M37 and M38. Additional UV lamp tests will be carried out during the last months of the experimentation.

Figure 17: The UV lamp installed at the outlet of the Daphniafilter at UDG pilot site

According to the integrated system scheme, the effluent of the Lumbrifilter is furtherly treated by the passage through the Daphniafilter as a polishing stage in order to improve the quality of the wastewater before the discharge or the reuse.

3.4 The Bio Solar Purification

However, in the context of the INNOQUA Project, an additional treatment has been proposed as alternative to the Daphniafilter. This technology is called the Biosolar Purification System (BSP) (Figure 19-22). The first version of the BSP was installed at the UDG demo site in M30 by Heliopure (HPT). Due to the withdrawal of this partner, this prototype was fixed and modified in the period M38 – M42. The start up the BSP (M42) has been done by feeding this system with the secondary effluent of the WWTP, and let the microalgae and biofilm growing.

Figure 18: Two 5 P.E. Lumbrifilter operated in parallel and the BSP system at UDG pilot site

Figure 19: Lumbrifilter and the BSP system at UDG pilot site

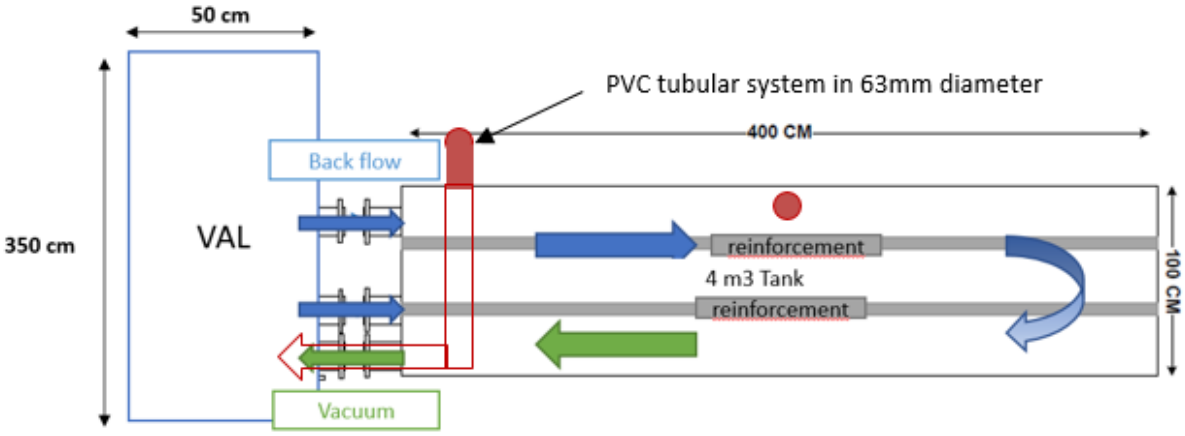

Figure 20: Basic layout of the BSP pilot: section view

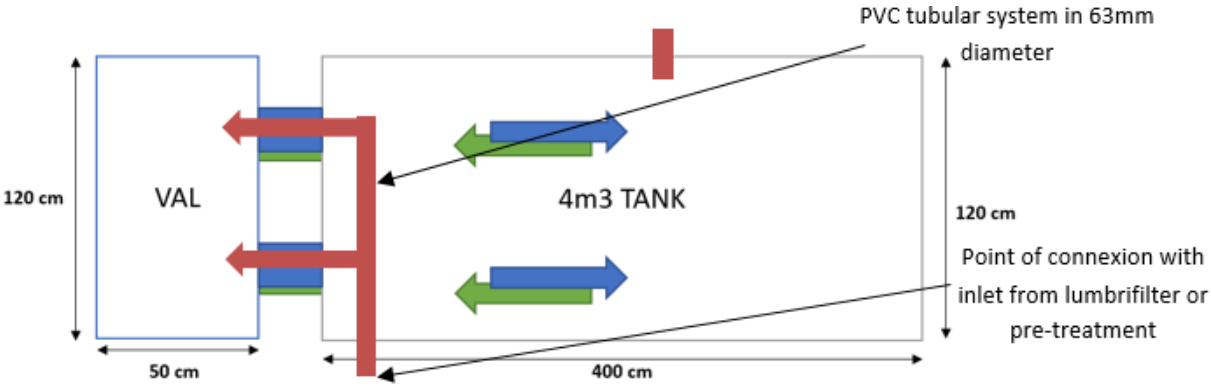

Figure 21: Basic layout of the BSP pilot: plan view

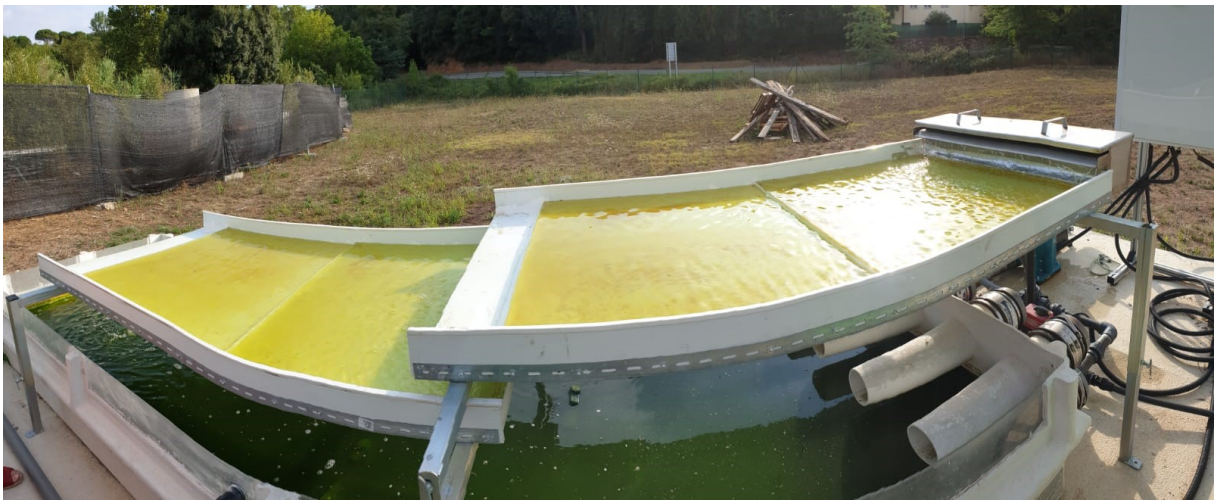

Figure 22: The BSP pilot plant: section view at UDG pilot site

Figure 23: Details of the BSP pilot plant: (a) recirculation pump, (b) influent feeding system, (c) control of the recirculation pump and (d) one of the four section of the BSP with the

4 Conclusions

The deliverable D4.2 is meant to provide a graphical overview of the state-of-the-art of the prototype pilot-plants installed at NUIG Galway and UDG facilities. As it can be seen from the pictures gathered along the different steps of the prototypes validation period, both the consortium partners have complied with the assigned task; e.i: (i) installation of the integrated INNOQUA system, (ii) in depth preliminary investigation of the respective technology, Lumbrifilter and Daphniafilter, respectively for NUIG and UDG, (iii) adaptation and improvement of the two main technologies, according to the experimental results obtained during the previous phase, (iv) start-up of the integrated INNOQUA system comprising the Lumbrifilter, the Daphniafilter and the UV lamp. Finally, although the bankruptcy of the BSP technology provider (see details in D5.1), the BSP pilot plant was successfully installed at UDG pilot site, and eventually started up. Currently, the overall evaluation of the integrated INNOQUA system is going on at both the pilot site facilities, in order to provide further insights on process operations and possible improvements and recommendations for the demo site partners.