STATEMENT OF VERIFICATION

Technology: HYDRO-1

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The verification process, whose results are summarized in this Statement, complies with the EU-ETV General Verification Protocol and with the ISO Standard 14034 on Environmental Management: Environmental Technology Verification.

Verification Body
Name: RINA SERVICES SPA
Contact: Giovanni D'ANGELO
Address: Via Corsica, 12, 16129 Genova, ITALY
Telephone: +39 010 5385 730
E-mail: giovanni.dangelo@rina.org
Web: www.rina.org

Proposer
Name: IRIDRA Srl
Contact: Fabio Masi
Address: via Alfonso La Marmora 51
Telephone: +39 3290759732
E-mail: masi@iridra.com
Web: www.iridra.com

Signed, 20/02/2022

Giovanni D'ANGELO, ETV Technical Manager

Fabio MASI, R&D Manager

ACCREDIA
L'ENTE ITALIANO DI ACCREDITAMENTO

ISP N° 069 E

Membro degli Accordi di Mutuo Riconoscimento EA, IAF e ILAC

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1. TECHNOLOGY DESCRIPTION

HYDRO-1 technology is based on two processes: an anaerobic treatment followed by nature-based solutions (NBS) with constructed wetland (CW), which allows obtaining a treated effluent that is suitable to be reused for irrigation purposes.

The first anaerobic reactor (AR) is composed on two micro reactors with square-shaped body where anaerobic wastewater treatment takes place, i.e. biological wastewater treatment carried out without using air or oxygen, leading to low amount of sludge produced, and offering the possibility to recover the biogas produced by the anaerobic metabolism. In this case two identical rectangular reactors have been installed (2.4 x 2.4 m) with a total height of 4 m. The total volume of the reactors (up to overflow) is 41 m^3. Then, the AR effluent is directed to the CW stage, which consists in a hybrid combination of Vertical Subsurface Flow (VF) CWs. The CW is designed with two stages: 1st stage, saturated downflow (VF SAT – 250 m^2); 2nd stage unsaturated intermittent load (VF UNSAT – 600 m^2). VF SAT is filled with gravel, while VF UNSAT is filled with gravel and an intermediate sand layer.

The process that takes place in the anaerobic reactor consists of the following phases. Wastewater flows upwards through a sludge bed composed by anaerobic biological sludge which occupies about half the volume of the reactor. There, the anaerobic microorganisms decompose the organic matter of sewage, generating biogas. The CW stage utilizes the complex physical – chemical – biological processes, dominant for the pollutants' removal. Saturated VF CW is continuously fed (with the effluent stream of the AR), over the top of the bed and for the whole surface, maintaining saturated conditions and developing anaerobic/anoxic conditions. Wastewater is intended to stay beneath the surface of the gravel bed and flow through the roots and rhizomes of the plants and the gravel pores. The inert material is maintained water saturated. This solution is suitable to remove organic and solid loads, as well as to provide partial denitrification, if nitrate nitrogen is available. In unsaturated vertical subsurface flow (VF) wetland, wastewater is intermittently pumped on the top of the beds and infiltrates vertically within the inert material. The unsaturated VF wetland is divided in two feeding lines and offers the possibility of an alternate feeding system, to enhance the prevalence of unsaturated conditions, which occur through the transfer of large quantities of oxygen inside the main bed filled with coarse sand. The high oxygen transfer is suitable to remove the organic matter and perform nitrification satisfactorily.

Figure 1. Anaerobic reactor (AR)

Figure 2. Saturated vertical flow constructed wetland (VF SAT)

Figure 3. Unsaturated vertical flow constructed wetland (VF UNSAT)

2. APPLICATION

2.1 MATRIX

Table 1. Intended application

Technology area	Technology purpose	Technical conditions
Water Treatment	Class A requirements for reclaimed	Suitable for touristic sites: winter, cold humid

and monitoring	water quality class in terms of TSS, BOD_5, and turbidity, according to the EU Regulation 2020/741	climate and lower number of residents; summer, hot arid climate and higher number of residents, increased by the anticipated tourism.

2.2. PURPOSE

The system enables to reclaim a large amount of water and nutrients (TN and TP) that, if coupled with a disinfection unit (e.g. UV irradiation), can be reused in agriculture under class A reclaimed water quality of EU Regulation 2020/741, i.e. permitting a reuse and recover of water and nutrients with minimum operational and maintenance cost in comparison to conventional technologies (lower sludge production, and manpower) for the cultivation of all the crop categories defined by the European regulation, i.e. crops for food, feed, industrial, energy or seed production. Finally, biogas from anaerobic process can be also collected and reused.

2.3 CONDITION OF OPERATION AND USE

The performance claims are intended to be robust against change of conditions that could be encountered in touristic areas of the Mediterranean region between winter (cold humid climate and lower number of residents) and summer (hot arid climate and higher number of residents, increased by the anticipated tourism).

2.4 VERIFICATION PARAMETERS DEFINITION SUMMARY

HYDRO-1 candidates to ETV for the following performance parameters: (i) Total suspended solids (TSS) concentration in the final effluent: < 10 mg/L in 90% of the samples, none of the values of the samples exceed the maximum deviation limit of 100% of the indicated value (Class A requirements for Reclaimed water quality according to EU Regulation 2020/741); (ii) BOD_5 concentration in the final effluent: < 10 mg/L in 90% of the samples, none of the values of the samples exceed the maximum deviation limit of 100% of the indicated value (Class A requirements for Reclaimed water quality according to EU Regulation 2020/741); (iii) Turbidity below < 5 NTU in 90% of the samples, none of the values of the samples exceed the maximum deviation limit of 100% of the indicated value (Class A requirements for Reclaimed water quality according to EU Regulation 2020/741); (iv) COD concentration in the final effluent is always: < 80 mg/L; (v) Sludge yield < 0.2 kg VS/ kg COD removed; (vi) Biogas production: > 0.3 m3 biogas/kg $COD_{removed}$; (vi) Treatment load in winter period (tested flow rate minimum 15 m^3/d), AR: Hydraulic loading rate (HLR) minimum 0.36 m3/m3/d, CW: HLR minimum 0.018 m3/m2/d; (vii) Treatment load in summer period (tested flow rate maximum 100 m^3/d), AR: HLR maximum 2.44 m3/m3/d, CW: HLR maximum 0.118 m3/m2/d; (viii) > 60% N-NH_4 removal in summer period for 90% of the samples; (ix) > 90 % COD removal in summer period for 90% of the samples; (x) > 90% TSS removal in summer for 90% of the samples; (xi) > 10000 m^3/y of reclaimed water; (xii) > 300 kN/y and > 30 kP/y from reclaimed water for fertigation.

3. TEST AND ANALYSIS DESIGN

3.1. EXISTING AND NEW DATA

HYDRO-1 is a technology developed within the Horizon2020 EU funded project of **HYDROUSA** (Demonstration of Water Loops with innovative Regenerative Business models for Mediterranean Region, www.hydrousa.org), a project submitted under the call CIRC-02-2016-2017 Water in the context of the circular economy (Grant Agreement No. 776643). HYDRO-1 was the main component of the HYDRO1 demo site of the project, realized in Antissa, in Lesbos island (Greece). HYDRO1 operation and monitoring were coordinated by the *Sanitary Engineering Laboratory of the National Technical University of Athens* (NTUA), which was also the coordinator of the project and by the *Water and Air Quality Laboratory of the University of Aegean* (UoA) (hereinafter “Aegean University Lab”), which is also a project partner. This ETV is based on the monitoring activities ran during the HYDROUSA project in 2021 and 2022.

3.2. LABORATORY OR FIELD CONDITIONS

Due to the lack of certified laboratories in Lesbos Island and the willingness to maximize the frequency of the sampling campaign, according to the available budget for monitoring activities, NTUA decided to realize a control room with a laboratory of analysis in situ (hereinafter called **"in situ lab"**) to monitor part of the pollutants of interest and to have daily presence on the HYDRO-1 site to coordinate its operation and monitoring. The in situ lab was hosted in a portable container and had an area dedicated to lab analysis. Additional parameters of particular interest were measured at the **Aegean University Lab**, located in the Lesbos island (Mytilene).

3.3. TEST AND ANALYSIS PARAMETERS

The performance parameters were tested within different winter and summer conditions, as follow.

Table 2. Tested operational conditions

Operational Parameter	**Temperature (°C)**		**Flow rate inlet (m^3/d)**		**Turbidity inlet (NTU)**		**COD inlet (mg/L)**		**BOD_5 inlet (mg/L)**		**TSS inlet (mg/L)**		**$N\text{-}NH_4$ inlet (mg/L)**	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Min	5	20	15	50	100		150	400	100	200	100	200	30	30
Max	20	35	30*	100*	300		500	1000	300	400	400	400	60	60
** The technology can be implemented by modules in order to fulfil different ranges of flow rate*														

Performance Parameter	**Turbidity outlet (NTU)**	**COD outlet (mg/L)**	**BOD_5 outlet (mg/L)**	**TSS outlet (mg/L)**	**$N\text{-}NH_4$ outlet (mg/L)**
Min	2	20	5	5	2
Max	5*	80	10*	10*	25
** Class A requirements for reclaimed water quality according to EU Regulation 2020/741*					

3.5. TESTS AND ANALYSIS METHODS SUMMARY

NTUA has developed a detailed test design and quality procedure to assure the validity of the data collected, in order to successfully monitor the HYDRO 1 site in line with the quality required by both the H2020 project monitoring and ETV. The procedure for Test design, reference analysis and measurement, data management, quality assurance, and test report requirements are detailed in the SVP. Water quality parameters were tested with Standard Methods (APHA, 2005), while operational parameter where monitored with dedicated sensor (e.g. temperature) and installations (e.g. flow meter).

3.6. PARAMETERS MEASURED

The main monitored parameters were: (i) performance parameters: COD, TSS, BOD5, Turbidity, N-NH4, TN, sludge, biogas production; (ii) operational parameters: flow inlet, pH, Temperature, precipitation, pressure (biogas collection).

4. VERIFICATION RESULTS

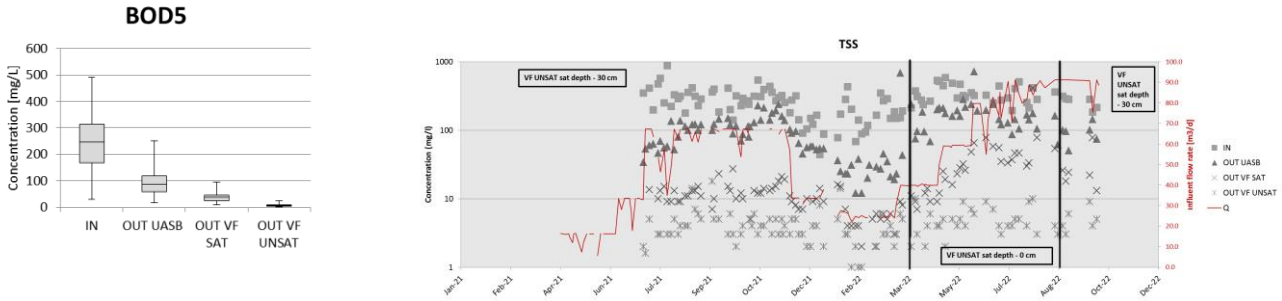
In the table below, is presented a sample of analysis results in the summer and winter period from the real system. The results consider the overall performance of the HYDRO-1 Demo Scale in terms of treatment performance.

Table 3. Quality of the inlet and outlet wastewater observed in the monitoring period 2021-2022

Parameter	**IN (mg/L)**	**St.dev.**	**OUT (mg/L)**	**St.dev**	**% rem**
COD	555	±254	31	±13	94
BOD_5	256	±105	6	±3	98

TSS	260	±131	4	±3	99
N-NH4	53.5	±18.3	4.2	±3.5	92
Turbidity (NTU)	218	±89	3	±1	-
COD	555	±254	31	±13	94
BOD5	256	±105	6	±3	98
TSS	260	±131	4	±3	99
N-NH4	53.5	±18.3	4.2	±3.5	92

Figure 4. Statistical analysis and temporal series from the monitoring period 2021-2022



5. ADDITIONAL INFORMATION INCLUDING ADDITIONAL PARAMETERS

The overall performance of the HYDRO-1 Demo Scale in terms of resource recovery in following reported.

Table 4. Recovered bioproducts observed in the monitoring period 2021-2022

Sludge production (t/y)	Biogas production (m3/y)	Water recovered (m3/y)	Resources recovered tN/y; tP/y
1.05	2500	20000	1.1 tN/y 0.15 tP/y

6. QUALITY ASSURANCE AND DEVIATION

The personnel and experts responsible for quality assurance as well as the different quality assurance activities were performed by RINA according to the EU Environmental Technology Verification Pilot Programme. General Verification Protocol. version 1.3 of 01 April 2018.