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D3.2 – Implementation Guidelines

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History			
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8	30/06/17	SUEZ	Final Submission of M13 Report
9			

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Executive Summary

The present document fits into the INNOQUA project in the Work Package 3 Technology integration, eco-design and pre-industrial scale up. The Task 3.3 implementation guidelines aims to provide useful information during prototype construction and implementation on the pilot sites to reduce the risks and costs of prototyping. The present document will be used as a handbook for the installations of the units on site.

The criteria used were pre-market requirements as defined in WP1, technical specifications gathered in WP2 and finally the data gathered from the pilot site representatives.

Version 1 of this document was submitted in M10. For the latest edition of the document interviews have been conducted with some of the demonstration site managers and technology providers to take into consideration any site-specific concerns. Based upon these findings, this report aims to develop the specific installation, start-up, operation and maintenance protocols for each technology, and present these in a unified and easy to read format.

The final version of this document will be submitted in M16. This will form an operation and maintenance style document for operating and maintaining the pilot site reactors.

The document is divided into 3 sections; Chapter 1 provides a short description of the treatment technologies and how they can be integrated into the overall goal of the INNOQUA project. Chapter 2 describes each technology, incoming wastewater requirements, starting procedure and recommended maintenance practice. Information provided in this section was specified by each technology supplier. This information will feed into the costs and prototypes drawing and building for the next phase. Chapter 3 will feature the integrated systems where several INNOQUA technologies will be installed in series. The technology requirements and the risks and issues of integrating these technologies together will be detailed. Since using different technologies in series will have an impact on the unit's overall performance, the range of incoming wastewater values will be updated. Discussions on how the technologies can be integrated and overcoming potential issues are still on-going between the technology suppliers and pilot site coordinators. As a result, Chapter 3 will be completed in the final version of this document, planned for submission in M16.

To provide an inclusive view of the objective for the implementation guidelines document, this report aims to detail procedures for the system design, installation, connection, operation, and maintenance of each technology. The INNOQUA technologies consist of: the Lumbrifilter, the Daphniafilter, the Biosolar Purification and the UV technology.

1 Introduction

1.1 Aim of the INNOQUA Project

The aim of the INNOQUA project is to develop four selected low cost, small scale, sustainable technologies to provide integrated wastewater treatment solutions to address various market needs. These markets are anticipated to be rural and agricultural areas, sustainable home builders and developing countries. The INNOQUA Project commenced in June 2016 (M01) and version 1 of this report, Deliverable 3.2 (D3.2): Implementation guidelines for the integrated systems, was developed in M10. This document forms the updated version of the D3.2 Report and is due for submission in June 2017 (M13). A final version, detailing all requirements for the integrated systems will be submitted in September 2017 (M16).

1.2 Aim of Work Package 3

The objective of Work Package 3 (WP3) is to prepare documentations and materials based on previously defined technical specifications (WP2) to develop prototypes of the integrated INNOQUA systems (WP4) and proceed them to a demonstration site stage (WP5). To achieve this the objectives are to provide an overview and specification of each technology and assess and optimise the environmental, engineering and economic impacts of each technology.

1.3 Aim of Deliverable 3.2

The aim of D3.2 is to provide a general overview of the operation, connection and maintenance requirements for each INNOQUA technology and highlight any requirements or risk when integrating these technologies. D3.2 will then be used to input vital information during prototype construction and implementation on the pilot sites, as shown in Figure 1.
Feeding into D3.2 will be the pre-market requirements defined in D1.1 and the specifications for the technologies in D2.1.

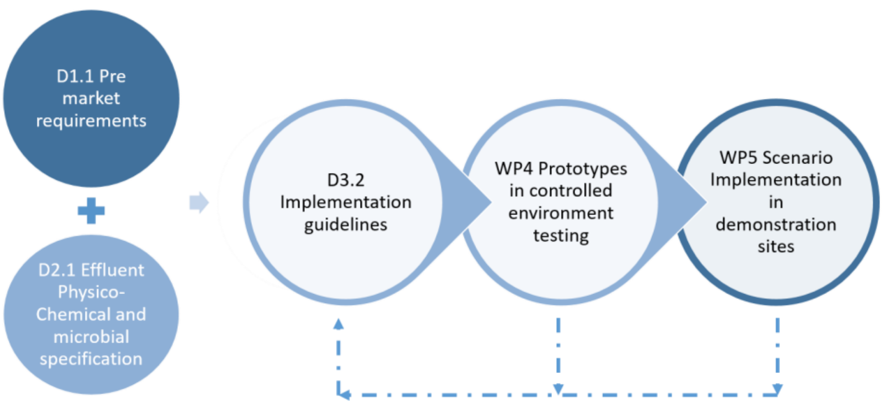

Figure 1: Relation with other WPs and Deliverables

D3.2 will be updated in M10, M13 and M16 of the INNOQUA project

1.3.1 Outcomes of Deliverable 3.2

The present task (Task 3.3) will provide deliverable (D3.2) for the following work packages: WP4 and WP5. It comprises the implementation guidelines for each technology to be used as a standalone unit, or if integrated with the other technologies.

The present document is divided in two main sections. The first iteration of this document detailed the individual technologies specific requirements.

The technologies are listed below. For each technology, the specific necessities for installation, connection and maintenance will be described.

- Lumbrifilter
- Daphniafilter
- Biosolar
- UV

It is anticipated that various monitoring and Control Units will be integrated with the treatment technology systems, designed to monitor and control received wastewater constituents, process conditions and effluent quality as required. These may be implemented on multiple modules depending the pilot needs.

The third iteration of this document (due M16) will comprise details for the integrated technologies, installed and operated in series. The risks and specific requirements for each set of different combinations will be detailed.

This will take into consideration the requirements upstream and downstream of each unit. The anticipated integrated INNOQUA Systems are listed below, though this is subject to further discussions with the technology suppliers and may be refined in Version 3 of this report:

- Monitoring and Control Unit
- Lumbrifilter – Daphinafilter – BSP – UV
- Lumbrifilter – Daphinafilter – BSP
- Lumbrifilter – Daphinafilter – UV
- Lumbrifilter – BSP
- Lumbrifilter – UV

The present document (D3.2) will then be used as input for WP4 and WP5, the prototype and demonstration site stage, see Figure 2.

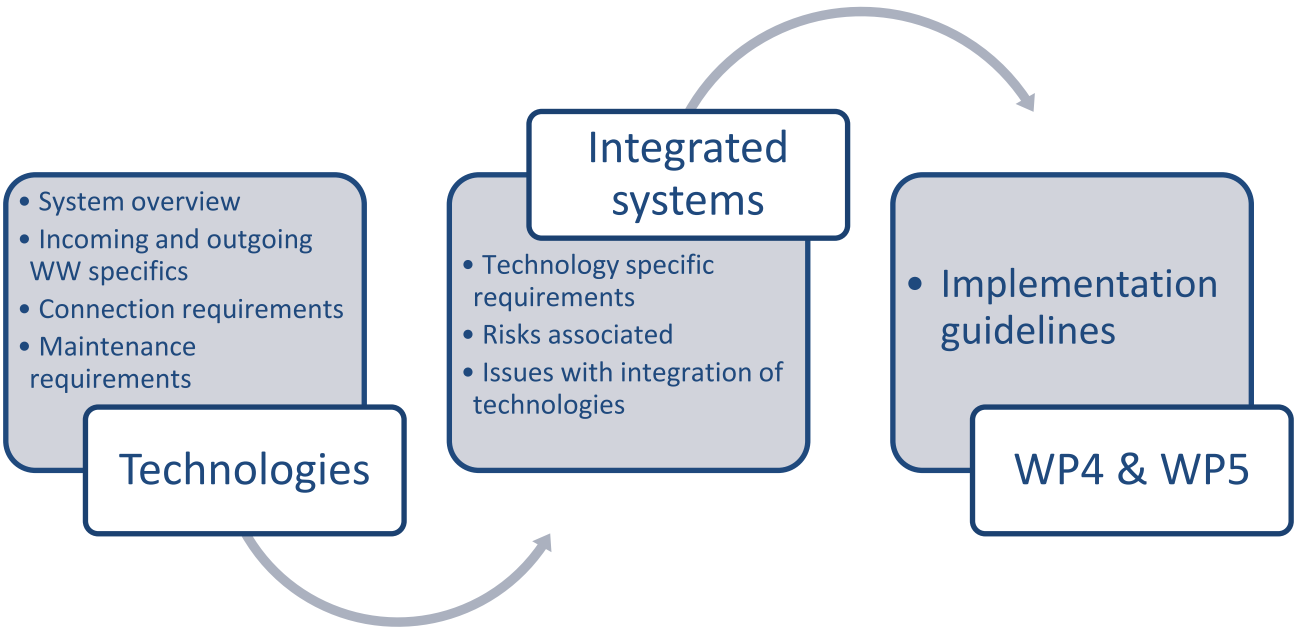

Figure 2: Illustration of the sections with T3.3 input/output and integration with WP4-WP5

1.4 Document Outline

In line with the requirements of the DOA and WP descriptions, this report undertakes the following:

- Details the implementation guideline for site installation
- Details the specific requirements to each technology for the installation, usage and maintenance as a standalone unit
- Characterises the incoming wastewater specifications for each unit
- Details the technology specific requirements to each unit for the installation, usage and maintenance if installed as part of the integrated system of technologies
- Description of the risks and issues that might arise from the integration of individual technologies to form the integrated INNOQUA system

2 INNOQUA Technologies

2.1 Lumbrifilter

2.1.1 System Overview

The overall process of wastewater lumbrifiltration ensures efficient solid-liquid separation of effluents through fine sieving (pretreatment), wastewater treatment by lumbrifiltration and reduction of solid waste volumes (associated with pretreatment and lumbrifiltration residues) by lumbricomposting.

Lumbrifiltration is an aerobic biological wastewater treatment process, with a fixed culture supported on a coarse bed, suitable for domestic effluents. Wood chips (substrate) are used as filtering medium and support for scrub biomass (aerobic bacteria). The inoculum of earthworms (responsible for digesting organics) within the filter contributes to biological oxidation, alongside microorganisms.

Furthermore, it should be noted that solid by-products can be processed independently of the lumbrifiltration/Lumbricomposting technology and used in combination with conventional sludge treatment systems. Lombrifiltration is designed to treat sewage derived effluents (domestic or industrial wastewater), however, it is anticipated that approximately 20 to 30% of the incoming flow may consist of rainwater.

2.1.2 Incoming Wastewater Specification

The acceptable ranges for the main parameters of the influent water to the Lumbrifilter are listed in the tables below.

Table 1: Mean parameters for incoming wastewater (PE - France)

Parameter	Flow	BOD5	COD	TSS		NK	TP
Mean PE	150 l/d	60 g/d	120 g/d	70 g/d		15 g/d	4 g/d

Table 2: Minimum parameters for expected elimination rates (France)

Parameter	Pathogens	BOD5	COD	TSS	NK	TP
Minimum	-	35mg/L (60%)	200mg/L (60%)	50%	-	-

Table 3: Maximum parameters for expected elimination rates (France)

Parameter	Pathogens	BOD5	COD	TSS	NK	TP
Maximum	100 bacteria/ 100ml	25mg/L (80%)	125mg/L (75%)	35mg/L (90%)	15mg/L (70%)	2mg/L (80%)

The parameter used to determine the number of population equivalents (PE) is BOD5. 60g/day defined one PE/day. On average in France this is equivalent to 150 litre/day.

Table 4 below details the qualities of rejection at the output of the lumbrifilter. It is observed that the lumbrifilter aims to lower most of the parameters under the standard "sensitive zones", see Table 4.

Bacteriology, orthophosphates and nitrates at the outlet of the lumbrifilter do not meet our objective of quality (rejection standards in sensitive areas, according to French regulations). Subsequent treatment of these elements is therefore necessary. Examples of suitable post-treatment include Biomedia for the treatment of residual nitrogen, apatite for the treatment of residual orthophosphates and UV for the treatment of residual pathogenic bacteria.

If in some cases the objective is agricultural re-use of water at 100%, post-treatment of nitrogen (NO3) and phosphorus (PO4) is not necessary, however the pathogenic bacteriology must be treated (by UV).

Table 4: Mean parameters of incoming wastewater and rejections of Lumbrifilter. Standards for sensitive areas in France Example: Combaillaux (industrial pilot of 500 PE), after 10 years of operation

Parameter	2015-2016			
	Input Plant	Output Lumbrifilter		Standards
	Average value	Average value	Efficiency (%)	Vulnerable areas (concentration / %)
TSS (mg/L)	329	22	93,19	Maximum 35 mg/l or 90% of efficiency
COD (mg/L)	737	84	88,58	Maximum 125 mg/l or 75% of efficiency
BOD5 (mg/L)	329	8	97,52	Maximum 25 mg/l or 80% of efficiency
TN (mg/L)	93	25	73,12	Maximum 15 mg/l or 70% of efficiency
TKN (mg/L)	93	5	-	-
NO3 (mg/L)	<1	20	-	-
NO2 (mg/L)	<1	<1	-	-
TP (mg/L)	10	9	17,59	Maximum 2 mg/l or 80% of efficiency
E. Coli (germs/100ml)	20 178 692	1 374 711	93,19	Maximum 200 germs/100ml (Class A) & 1000 germs/100ml (Class B)
Enterococcus (germs/100ml)	4 738 923	255 055	94,62	Maximum 1000 germs/ 100ml

2.1.3 Connection Requirements

Lumbrifiltration works is available to receive flow 24 hours a day. The main equipment works in daily cycles (on/off time) as required. No equipment must operate continuously (except for process controls).

The tanks, which allow the transfer between the inlet and the outlet of the water, are typically made of polyester, manufactured by filamentary winding or helical and fiberglass reinforced resin. For the INNOQUA application, HDPE will be utilised.

These techniques and materials offer significant advantages to the product: resistance to corrosion, exceptional mechanical strength, low weight and modularity.

The pipes which allow the connections between the different processes can be made of PVC pressure pipes, with diameters between 60mm and 150mm, depending on the number of inhabitants (PE) to be treated (10, 50, 100 PE). The number of inhabitants defined the model of micro lombri-plant to be installed (INNOQUA project).

Use spiral nozzles with a solid cone, insensitive to the risk of clogging to spray the water on the lumbrifilter. The spiral nozzles operate per the principle of the deflection of a jet.

One or more pumps are required, depending on the model of the micro lumbri-plant (submersible pumps). There are several models on the market, adapted to micro-plant.

2.1.4 Starting procedure

For 50PE applications, pre-treatment by fine-sieving is required to reduce sludge production within the filter. For INNOQUA demonstration site applications (typically <10PE), this step will not be required. The Lumbrifilter (**Error! Reference source not found.**) is the central and original part of the wastewater treatment process by lumbrifiltration. This treatment is ensured by an active layer (CA) composed of wood chips of the same particle size.

The starting procedure goes as follows:

- Before introducing the earthworms into the lumbrifilter, it is necessary to activate the spraying of the wastewater for one week, to moisten the entire active layer and to help the installation of the bacterial population. Then, 24 hours after the installation of the earthworms, one can activate normal watering. (During the lifetime of the lumbrifilter no addition of earthworms is necessary (auto-reproduction in the lumbrifilter)
- Introduce a minimum of 5000 individuals per square meter (m^2), all stages combined, including the cocoons.

The degradation of organic matter by microorganisms produces bacterial biomass, which in turn must be degraded to avoid clogging, the major part of this degradation is achieved by ingestion and digestion in the earthworm.

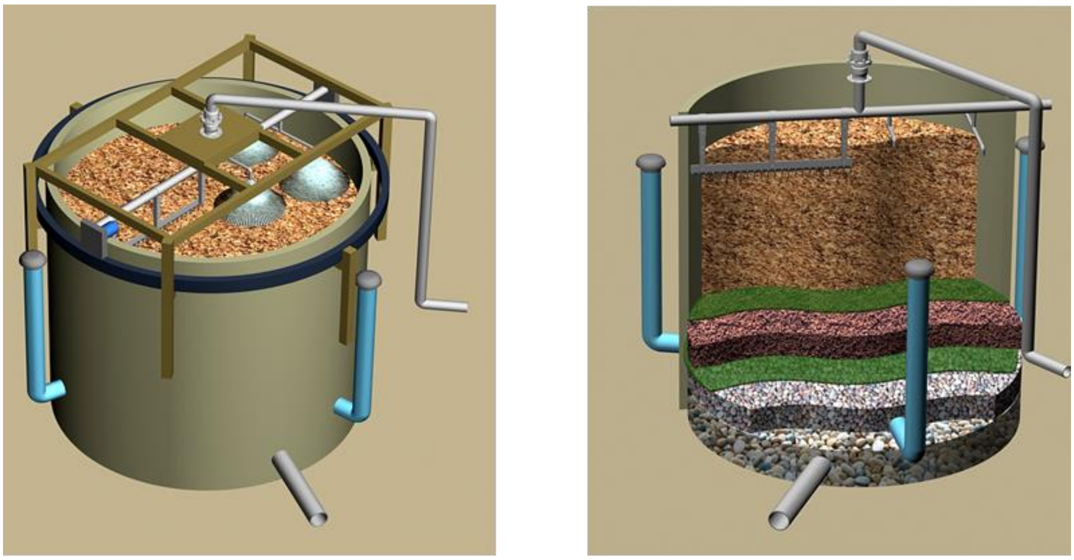

Figure 3: Lumbrifilter diagram for 10 PE by LombriTek in the Department of Hérault (France)

- Start-up after maintenance must be immediate. At the start of the system, it is not required to analyse the water at the outlet of the lumbrifilter, before two months (the time needed to stabilise the system).

2.1.5 Maintenance Requirements and considerations

A highly-automated process may be required to enable monitoring of all the steps of the water path from the inlet to the outlet. For the operation and maintenance of the pilot plants, site-specific restrictions will govern the frequency of site visits and hence the possibility of completing all the recommended maintenance works provided in this document. This section provides recommended maintenance routines for the lumbrifilter and lumbricomposting process, however it is understood that some compromises may need to be applied (particularly for rural or difficult to access sites). Interviews were held with key demonstration site managers to gain an understanding of some of the site-specific concerns regarding maintenance of the technology. The general points have been incorporated into this section.

2.1.5.1 Weekly

- Levels of the waste collection bins.
- Routine inspection checks (visual inspections, etc.) should be completed once per week. To avoid unexpected events, alarm systems can be installed (send SMS or Email to the responsible operative). Exact visual checks will be provided within the final version of this document.

These checks are likely to reduce in frequency throughout the pilot study as the process becomes more stable. This will be particularly important for demonstration sites in remote locations.

2.1.5.2 Monthly

- Solid waste from sanitation is collected in bins at the collection points. Once a month, this waste must be recovered and mixed, and earthworms introduced (either from existing composting pile or by extracting from lumbrifilter.
- Each month stir the surface content of the lumbrifilter with a light digging (if there is no automatic system) and check the condition of the spray nozzles (clogging).

2.1.5.3 Every 2-4 Months

- Level of the wood chips in the lumbrifilter.
- At the end of the 3 month lumbricomposting period, the whole is screened, the lumbricompost separated from the inert waste and the earthworms are recovered. The lumbricompost can be recovered.

The lumbricomposting process appears to be quite labour intensive, which may not be suitable to some pilot site locations. Further considerations for a less intensive maintenance strategy may need to be considered to ensure that this is achievable for all pilot site applications.

Consideration will need to be taken as to whether the pilot lumbrifilter system is installed over or underground for each site. Among the site-specific conditions (i.e. temperature and requirement for protection from frost), specific market objectives of the pilot studies will need to be considered. For instance, if the main aim is to prove to potential end-users that effective effluent treatment can be installed whilst ensuring minimum impact on aesthetics, then the system should be installed underground. If however the main aim is to highlight the technical aspects of the treatment processes occurring, then the system should be installed over-ground so that these can be visually inspected.
Any further details regarding the restrictions, the ideal operating ranges for the technology will be considered during the prototype trial period and provided in the final version of this document.

2.2 Daphniafilter

2.2.1 System Overview

The aim of the Daphniafilter technology is to achieve the required water quality standards, with a cost-effective process that does not require the use of chemicals. The technology is based on the filtration activity of filter feeder organisms relying to the *Cladocera* order (mainly Daphnia Magna). While large particles are easily removed from wastewater via settling tanks or filtering techniques, the settling velocity of small particles is too low and they are not easily retained.
These organisms ingest the suspended organics with a maximum particle size up to 35-40 µm. The population of Daphnia in the system is dynamic and depends on different factors, being the substrate availability (either, their limitation and excess), the turbulence (flow velocities in the system) and the water temperature some of the main affecting parameters. Daphnia development is ensured above 6°C and up to 26°C. The Daphniafilter technology is implemented after secondary treatment processes.

The main goal of the Daphniafilter unit is the removal of suspended solids and pathogens in order to obtain good quality effluent water which parameters fit the regulated discharge limits of most countries.

2.2.2 Incoming Wastewater Specification

The acceptable ranges for the main parameters of the influent water to Daphniafilter are listed inTable 5.

Table 5: Maximum and minimum influent parameters accepted for the Daphniafilter unit

Parameter	Units	Max Inf. permitted	Min Inf. permitted
Dissolved Oxygen	mg O_2 L^{-1}	-	0.5
pH	-	9	6.5
Conductivity	mS cm^{-1}	12	-
Temperature	°C	26	6
Ammonium	mg $N\text{-}NH_4^+$ L^{-1}	15 (40)[a]	-
Free ammonia	mg $N\text{-}NH_3$ L^{-1}	2	-
Nitrite	mg $N\text{-}NO_2^-$ L^{-1}	0.5 (2)[a]	-
Nitrate	mg $N\text{-}NO_3^-$ L^{-1}	25 (150)[a]	-
Phosphorus	mg $P\text{-}PO_4^{3-}$ L^{-1}	10 (15)[a]	-
Turbidity	FTU	Max to be determined (tested up to 27)	-
[a]: Critical values for Daphnia survival (toxicity); n.a.: not applicable.			

This unit takes advantage of the filtration activity of filter feeding organisms (Daphnia) to decrease the turbidity and pathogens present in the wastewater. It must be noted that the particulate suspended matter in the effluent of the Lumbrifilter is expected to mainly consist in organics and sludge. With the ingestion of these suspended solids by the Daphnia, part of the nutrients associated to the particulate matter, are also removed and the TKN and TP parameters decrease. Moreover, the concentrations of nitrogen and phosphorus soluble species decrease very slightly in the Daphniafilter mainly by the action of the biofilm formed in the tank walls.

2.2.3 Connection Requirements

The Daphniafilter system (Figure 4) has been designed with inlet and outlet connection pipes of 110 mm diameter to facilitate the connection with the other units and to avoiding clogging problems. The material of the pipes is preferable to be polyethylene, since it provides smooth surfaces avoiding biofilm and/or sludge attachment which helps to prevent clogging problems.

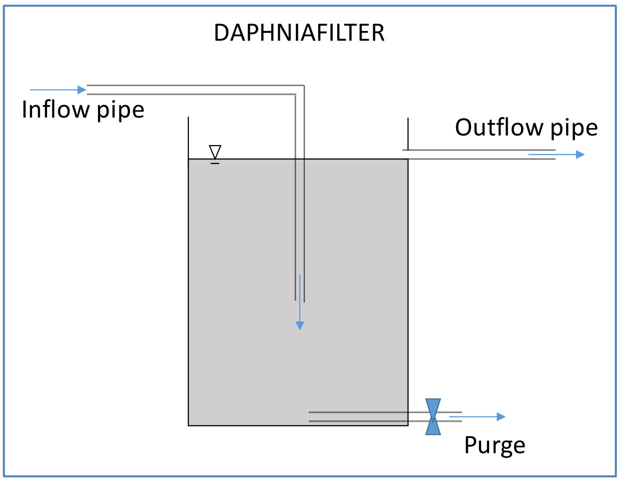

Figure 4: Scheme of the Daphniafilter unit

The water can flow into the system by gravity avoiding the use of pumps, whenever the Daphniafilter is in a lower level than the lumbrifilter. In peak flows situations exceeding the values permitted in the Daphniafilter, a buffer tank is required in order to laminate the inflow to this unit. In cases that the design of the whole facility does not permit gravity flow to the Daphniafilter a pump must be installed, with a flow rate that maintains a HRT of 24 hours in the unit (flow rate to be adjusted per Daphniafilter volume).

In case of a pump needed, electricity supply is required (230 V AC 50 Hz, or the specific local supply conditions). In any case, pumps will be provided by local suppliers in order to facilitate replacement in case of damage. Pump selection must follow the guiding compasses of low energy consumption, minimum maintenance requirements, long durability, and facility for the replacement of spared parts or the whole equipment.

2.2.4 Starting procedure

For the start-up of the Daphnia filter the following instructions should be followed:

- Fill the Daphniafilter with wastewater from the lumbrifilter
- Check for no secondary recirculation within the Daphniafilter
- Introduce Daphnia magna individuals with an initial concentration of 5 individuals per litre
- Check for Daphnia individuals to swim in a random way. Daphnia might also move due to phototaxing.

2.2.5 Maintenance Requirements

For the operation and maintenance of the pilot plants, site-specific restrictions will govern the frequency of site visits and hence the possibility of completing all the recommended maintenance works provided in this document. Interviews were held with key demonstration site managers to gain an understanding of some of the site-specific concerns regarding maintenance of the Daphniafilter technology. The general points have been incorporated into this section.

The following maintenance and routine checking is recommended for the good performance and operation of the Daphniafilter:

2.2.5.1 Weekly

- The plant will be designed to ensure sufficient levels, retention times and up-flow velocities are maintained, however it may be useful to check these parameters on a weekly basis. As the plant should be designed to operate within the required level and flow parameters, this should not be an essential check and so is not required on all sites at such frequencies.
- Provided that upstream processes are working effectively, there should be little carryover of coarse solid material. It may be desirable (where possible) to check inlet pipework for blockages at regular intervals if this is likely to be an intermittent issue. This is considered to be an integration issue and will be address in section 3 of the third iteration of this document.

2.2.5.2 Monthly

- A 1 litre syphon tube is used to extract exactly 10 litres of water from within the tank, 1 litre at a time from 10 different locations around the tank. This will obtain an average distribution of daphnia throughout the reactor. The full 10 litres of extracted waters are passed through a zooplankton net so that daphnia concentrations within the reactor can be quantified on a monthly basis. The typical operating range is 10-150 daphnia/litre. A reduction to below 10daphnia/L indicates that conditions are not optimal for operation and the reason for this must be investigated. (If for example the cause is low temperatures, then insulation can be applied and numbers allowed to naturally increase once again). It is anticipated that this maintenance check will only be required at such frequencies during start-up of the pilot plants. Reduced frequencies are likely to be required later in the pilot study and for real-life applications.

2.2.5.3 Annual

- To prevent the buildup of filamentous algae and deposits at the bottom of the tank, it is recommended that these areas are inspected annually to evaluate if a purge of the system is required. The actual requirement for a purge is likely to be less frequent than annual and is likely to be site specific. This is also more likely at to be required at the end of the summer months.

Prior to commencement of the study it is important to identify the site specific maximum summer and minimum winter operating temperatures. This will identify the requirement for insulation to maintain temperature within the operating range.

2.3 Biosolar

2.3.1 System Overview

The purpose of the Bio-Solar Purification (BSP) technology is to treat wastewater for reuse, recycle of wastewater or discharge in sensitive aquatic systems. The technology uses sunlight and CO2 as only reagent creating the proper conditions for the intensification of natural phenomena which take place at the water/air interface. These phenomena enable the elimination of most hazardous microbial contaminants and hazardous substances as well as the treatment of mineral and organic contaminants.

The added value of the BSP system resides in its ability to recover mineral nitrogen and phosphorus contaminants which are not treated in conventional WWT plants and transforming them into photosynthetic biomass making them usable as organic fertilisers. The process produces a water/photosynthetic biomass blend that can either be used as such in watering and agricultural irrigation or go through a separation process creating clear water suitable for a variety of uses from domestic to industrial and a non-toxic photosynthetic biomass separately.

2.3.2 Incoming Wastewater Specification

BioSolar operation is based on a bacteria-microalgae symbiosis that will adapt to the contents of the specific wastewater to treat. For this reason, we cannot design the reactor for a specific load. The performance of the reactor therefore will depend entirely on the incoming wastewater characteristic's so an efficiency treatment cannot be assumed at this point.

On Table 6 the incoming wastewater specifications and on Table 7 the physico-chemical specifications of incoming wastewater. Values for the minimum, maximum and average numbers for the BioSolar operation are provided. These values are referenced from previous trials from BioSolar technology with wastewater. These values are to be use as indicative only, further testing with a different range of values are required.

Table 6: Incoming wastewater specifications

Parameter	Min value (mg/L)	Max value (mg/L)	Average Values
Total suspended solids	100	500	100
COD	200	600	215
BOD5	100	200	189
TN	30	120	40
TKN	50	70	-
NH4-N	15	60	26
NO3-N	0	20	-
NO2-N	-	-	-
TP	4	15	6
E coli	1.5E+06	2.8E+07	2.8E+06

Table 7: Physio-chemical specifications of incoming wastewater

Parameter	Min value	Max Value	Optimal Value
Incoming water temperature (°C)	10	40	25
pH	6	11	8

2.3.3 Connection Requirements

The BSP technology consists in an agitated reactor with a flexible incoming water feed position see Figure 5: BSP diagram bird's eye view (left) and BSP diagram cross sectional view (right). With consideration to the inlet and the outlet are not side by side. A connection can be made in the depth of the tank (ground level) as well as in overflow (1 m above ground level). Depending on the incoming water height one of these options may be preferable.

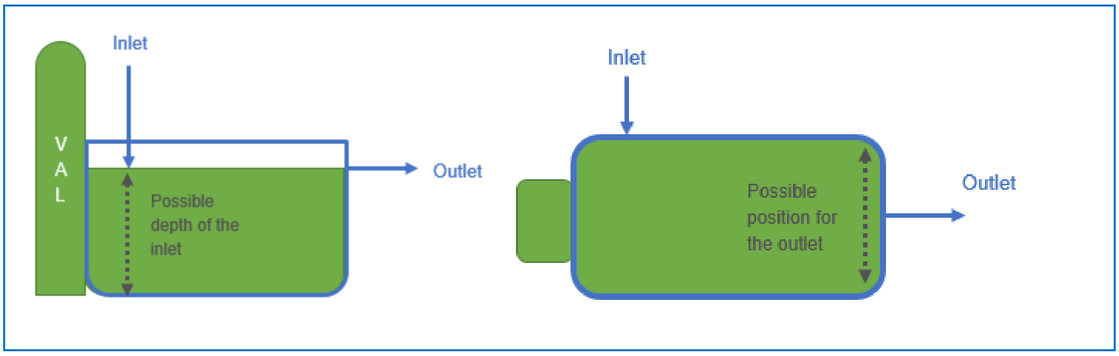

Figure 5: BSP diagram bird's eye view (left) and BSP diagram cross sectional view (right)

When functioning independently and for flow rates going from 0.1 to 10 m^3/h, the BSP reactors are fed by PVC piping. See Table 8 for piping specifications. The treated water outlet is always done by over flow with the same PVC piping. The incoming and outgoing pipeline size is flexible and can be modified if necessary.

Table 8: Piping specifications for inlet and outlet of Bio Solar system

Typology	Material	Size
Inlet piping	PVC	PN16 Ø63 DN50
Outlet piping	PVC	PN16 Ø63 DN50

2.3.4 Starting procedure

For the start-up of the unit the following instructions should be followed:

- Fill the tanks with wastewater after pre-treatment i.e. a simple screening or lumbrifilter or primary decantation. The wastewater must contain organic matter (BOD, COD), NH_4, NO_3 and PO_4
- Start circulation and gas exchange through the VAL (vacuum air-lift) = T0
- Introduce the microbial starter (a microbial consortium made locally containing bacteria, fungi, photosynthetic bacteria and microalgae)
- Run the system and control the system with pH coupled to CO2 supply. Analyse NH4 and as soon as NH4 is consumed (after 4 to 10 days) start the renewing of a semi continuous operation until the biomass is acclimatised
- Run the system in a semi-continuous diurnal-night operating procedure after 2 or 3 weeks from the T0
- Diurnal phase operating procedure: wastewater supply is done with a dilution rate based on the residence time necessary to treat. This residence time is the first operating parameter to determine according quality of wastewater entering the BSP (Bio-Solar Purification) reactor. Recirculation and CO2 injection through the VAL is controlled by pH value
- Night phase operating procedure: wastewater supply and CO2 injection are stopped. Recirculation and air injection through the VAL are the same than during the diurnal phase

Once the system is started it can be operated without starting procedure for many years unless the system is emptied.

2.3.5 Maintenance Requirements

For the operation and maintenance of the pilot plants, site specific restrictions will govern the frequency of site visits and hence the possibility of completing all the recommended maintenance works provided in this document. Interviews were held with key demonstration site managers to gain an understanding of some of the site-specific concerns regarding maintenance of the technology. The general points have been incorporated into this section.

2.3.5.1 Daily

- When the BSP system is turned-off, maintenance must be carried out on the vacuum pump from the VAL system. The pump needs to be lubricated with WD40 and left idling for 30 minutes before being turned-off for indefinite periods of time

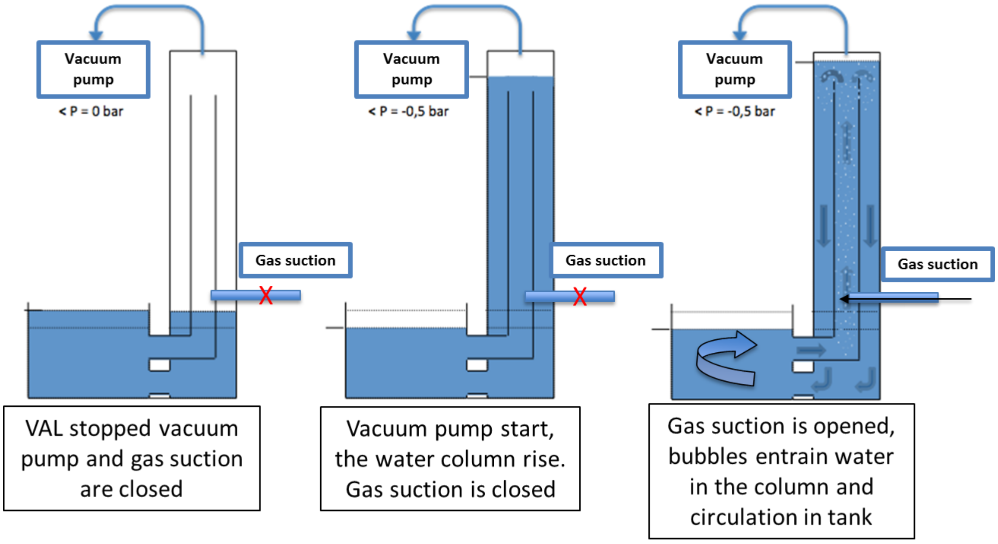

Figure 6: Vacuum Air-Lift principles (Patented technology)

If the VAL system must be turned off at daily or weekly intervals for maintenance, then this solution is unlikely to be suitable for many of the pilot sites.

2.3.5.2 Weekly

- The light entrance surfaces in contact with the wastewater will become covered with a layer of microalgae which will inhibit the light penetration in the depth of the reactor. These surfaces need to be cleaned regularly (from once a day to once a week). Depending on the frequency necessary the cleaning system can be automated and thus left out of the maintenance requirements. An automated cleaning system is likely to be more suitable for many of the pilot sites.

2.3.5.3 Monthly

- If daily maintenance cannot be completed, then as a minimum the oil-level of the pump must be checked every month.

The prototypes and pilot studies must be utilised to identify the minimum maintenance requirements for the system so that the most suitable markets can be identified for real-life application.

2.4 UV

2.4.1 System Overview

The UV-system is designed to disinfect water with UV-exposure. For this purpose, several UV-lamps are placed in the liquid flow and powered via a separate control unit.

The ultraviolet disinfection process inactivates germs, viruses, bacteria, spores, fungi, algae and other micro-organisms quickly and safely. The specific properties of treated liquids such as colour, odour, taste and acidity remain unchanged. Depending on the model, various options can be fitted to simplify the use of the system and to optimise the quality.

Figure 7 illustrates the main aspects of the construction of the UV-system. The diagram shows all possible applicable options. The actual situation can vary from the diagram depending on the application and the size of the system.

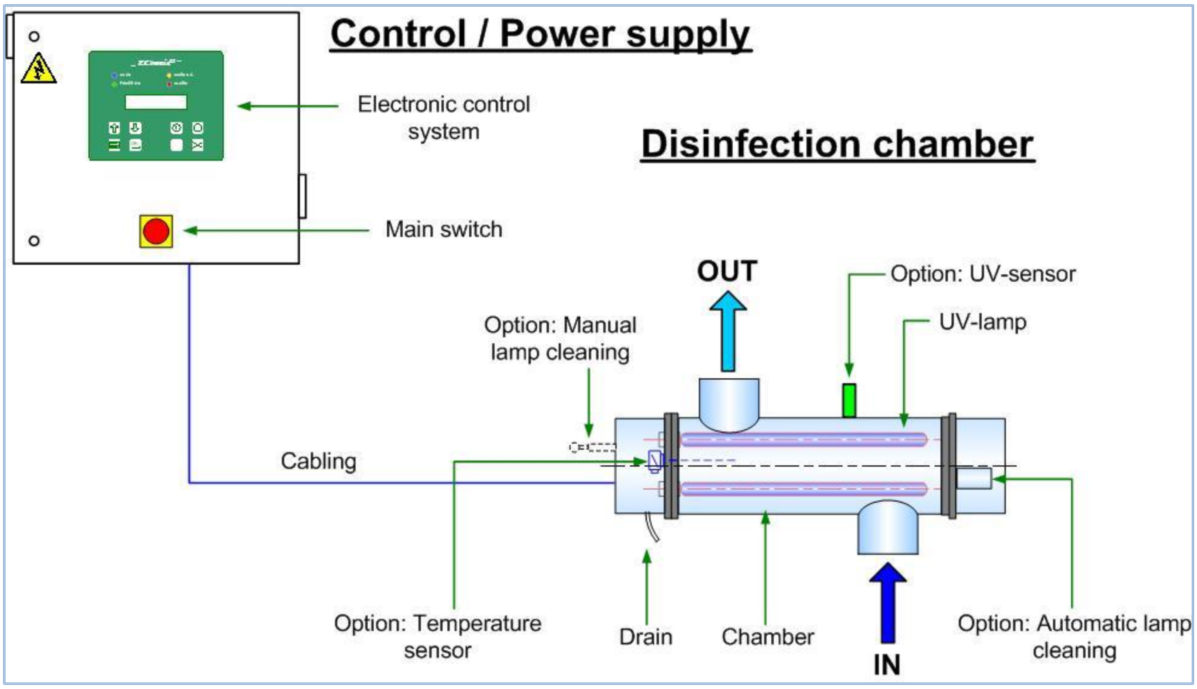

Figure 7: UV-system

2.4.2 Incoming and Outgoing Wastewater Specification

UV Transmission (UVT) provides the necessary information as to the amount of light lost due to scattering and absorption through a water column, and therefore is a critical component of effective UV disinfection. To ensure proper inactivation of pathogens, an effective UV dose needs to be calculated based on UVT, UV light intensity and flow rate (exposure time).

For incoming and outgoing characteristics, see Table 9 below.

Table 9: Incoming wastewater specifications for the UV-system

Parameter	Min value	Max value
Suspended solids	0 mg/l	15 mg/l
BOD5	0 mg/l	10 mg/l
Iron content	0 mg/l	4 mg/l
Ecoli	0ml	100.000 / 100ml
Transmission	62%	100%
Dose	25mJ/cm2	40mJ/cm2

2.4.3 Connection Requirements

The UV-system has specific connection requirements to operate according to the design specifications. The disinfection chamber consists of the following components:

- Chamber, which is the main component of the UV-system. The in and out connections for the liquid are at the two ends of the chamber on all types (see Figure 8).

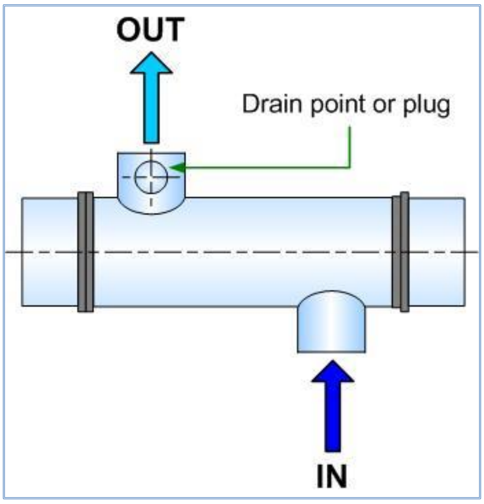

Figure 8: Illustration of the UV-system installed in a pipe

Two end flanges are fitted on the top sides of the chamber to ensure the detection of the lamps and any cleaning mechanism present. The fitted accessories are covered on both sides with a hood that also contains the cable glands.
As standard, there are also provisions in the chamber for a UV-sensor (optional), for venting and draining the system (optional) and for removing liquid from the control compartment. The size and the design of the chamber depend on the required disinfection capacity and the nature of the liquid.
In Table 10, the material requirements for the UV-system to run correctly.

Table 10: Description of the material used and the requirements for UV maintenance

Specification	Description
Material	SS 316L, according to AISI
Internal finish	Ra 0,8µm
Connections	2" BSP inner thread
Degree of protection	IP 54
Weight dry	10 kg
Weight wet	18kg
Pipe diameter	114mm
Number of lamps	1
Nominal pressure	7 bar
Test pressure	10 bar

- UV-lamps, whose number and type built into the system depend on the system size and the nature of the liquid that must be disinfected. The lamps are placed in quartz sleeves and therefore do not come into direct contact with the liquid. They can be fitted from either flanges. This should be done per a strict procedure.

Before starting the system, it takes 3 to 5 minutes before the full UV intensity is reached. After this time, you can switch the pump to let the water through the chamber.

The life span of the lamps will be drastically reduced if they are repeatedly switched on and off. This results in decreasing UV intensity. Any contaminants on the quartz sleeves also lead to reduced UV output.

2.4.4 Starting procedure

Complete the mechanical and electrical installation work, then take the following precautionary measures:

- The pipework system with the UV-system must be completely filled with liquid and de-aerated
- The flow-rate of the liquid medium must be sufficiently high to cool the system
- Check whether the circuit breakers in the control cabinet are in the correct position
- Check whether the correct supply voltage is present on the connection contacts in the control cabinet.

2.4.5 Maintenance Requirements

The quartz sleeves should be cleaned on a regular basis. The optimum frequency for doing this depends on the liquid and needs be established based on on-hand experience working with the system.

If the optional cleaning mechanism is used, cleaning can take place while the system is operating. If there is no cleaning mechanism fitted, then one of the following methods must be used:

- Chemical cleaning
- Disassembling and manual cleaning of the quartz tubes.

The UV sensor measures the efficiency of the UV lamps in combination with the level of contamination of the water. A quartz window on the inside of the disinfection chamber covers the measuring surface of the sensor. Contamination may occur on this window and has a negative effect on the UV measurement.

2.4.6 Annual

- Filter for cabinet fan (option)
- Cleaning wiper
- UV-lamp
- Seal 15*25*8 (manual wipe)
- O-ring 32*5 (for quartz sleeve)
- O-ring NW25
- O-ring NW100
- O-ring 9.12*3.53 (UV-sensor)

2.4.7 Every 3 Years

- Usually every three years the quartz sleeve must be changed
- Quartz sleeve 867mm F200
- Teflon ring 34*4
- O-ring 30*3
- O-ring 120*4
- O-ring 10*2
- Boss wiper rod L28mm

Table 11: Maintenance schedule for each part of the UV-system

Parts	Every year	Every 3rd year	Security stock
Filter for cabinet fan (option)	2	-	2
Cleaning wiper	1	-	1
UV-lamp	1	-	1
Quartz sleeve 867mm F200	-	1	1
Seal 15*25*8 (manual wipe)	1	-	1
O-ring 32*5 (for quartz sleeve)	2	-	2
Teflon ring 34*4	-	2	2
O-ring 30*3	-	1	1
O-ring NW25	1	-	1
O-ring NW100	1	-	1
O-ring 120*4	-	1	1
O-ring 10*2	-	2	1
O-ring 9.12*3.53 (UV-sensor)	1	-	1
Safety pin 4*32 SST	-	-	1
Boss wiper rod L28mm	-	1	1
Handwipe guide bush	-	-	1

2.5 Monitoring and Control Unit

2.5.1 System Overview

The main aim of the MCU is to monitor and control the INNOQUA solution which can be based on multiples modules depending the pilot needs. These modules, which have been depicted previously, are the Lumbrifilter, Daphniafilter, Bio-solar technology and UV technology. The MCU consists of two key elements to measure and control INNOQUA solution which are: (i) IoT Elements and (ii) MCU Gateway. The IoT Elements are the responsible of managing the probes, sensors and actuators and interact with the MCU Gateway. Instead, the MCU Gateway is the responsible to centralise all the information gathered by IoT elements, analyse it and make-decisions. Also, the MCU Gateway provides the Human Machine Interface (HMI) to interact with the system and synchronise all the information with the Cloud.

In the following sections are introduced the starting process of the MCU, the connections requirements and the maintenance procedures.

2.5.2 Connection Requirements

2.5.2.1 Power Supply

Power Supply is required for MCU due to its electronical basis. Two elements of the MCU, MCU Gateway and IoT Element, require power supply. The operation and power of them is totally different and hence, their connection requirements also diverge. The IoT Element is only focused on metering taking advantage of the sensors and controlling the actuators, but all the decision-making and analytics is performed by the MCU Gateway. Moreover, the MCU Gateway has an embedded Human-Machine Interface (HMI) whose aim is to provide on-site solutions without external dependencies.

The MCU Gateway requires electrical power supply which should to introduce through a Micro USB female. The power supply connected to the Micro USB should to be able to provide 5V and 2.5A.

On the other hand, the IoT elements can be supplied by an electrical power supply or a solar panel. Concerning the electrical power supply, it should to provide 5V and 1A through Micro USB female connector. Instead, if the solar panel supply is used, the solar panel should to be mounted on a 45º holder with the aim of ensuring the maximum performance.

2.5.2.2 Pre-Filter Requirements for Volumetric Flow Meters

In the case of use volumetric flow sensors, it is important to avoid the passing of water with particulate matter because it can cause the paddle wheel blades to become jammed, providing not accurate volumetric flow reading. Therefore, the use of pre-filters is recommended if volumetric flow meters are installed.

2.5.3 Starting procedure

The starting procedure of the MCU is based on four processes which are: (i) link the MCU Gateway with the IoT Elements; (ii) probe and actuator setup; and (iii) probe calibration and (iv) MCU deployment.

2.5.3.1 Link the MCU Gateway with the IoT Elements

Initially, a MCU Gateway does not linked with the IoT Elements, and the user is responsible to carry this out.

Below, the steps to carry out this linking are detailed:

1. Turn on the MCU Gateway and IoT element
2. Navigate through MCU HMI until reach the Linking section
3. Introduce the URI of the IoT element which is available on the back of each device
4. Check the connectivity with the button check
5. Save the changes.

2.5.3.2 Probe and Actuator Setup

Once the IoT Elements are linked with MCU Gateway, the probes and actuators can be configured. MCU is prepared to work with heterogeneous sensors (e.g. volumetric flow sensors, ammonia concentration sensors, temperature sensors, etc.) and actuators (e.g. pumps, motors, etc.). Basically, the sensors integrated are classified as I2C (serial computer bus for attaching peripherals, analogical or digital (pulsed signal) sensors depending their output signal. Instead, the actuators are only classified as digital (pulsed signal). The MCU requires a previous setup before to work with them.

Below, the steps to configure the sensors are explained:

1. Turn on the MCU Gateway and IoT element with the specific sensor connected to its corresponding socket (I2C, digital and analogical input)
2. Navigate through MCU HMI until reach the IoT Element which contains the sensor to be configured
3. Enable the socket where the sensor has been connected and introduce the demanded information:
    a. I2C sensor, e.g. memory position where I2C protocol publish the metering
    b. Analogical sensor, e.g. output range of voltage of the sensor
    c. Digital sensor, e.g. sampling rate
4. Accept the introduced configurations by saving the information
5. Now, the sensor is configured.

Referring the actuators, the steps to configure them are explained:

6. Turn on the MCU Gateway and IoT element with the specific actuator connected to its corresponding socket (digital and analogical output).
7. Navigate through MCU HMI until reach the IoT Element which contains the actuator to be configured.

8. Enable the socket where the actuator has been connected and introduce the demanded information:
    a. Digital actuator, e.g. frequency and duration of the signal
9. Accept the introduced configurations by saving the information
10. Now, the actuator is configured.

2.5.3.3 Probe Calibration

The calibration process can be based on one point calibration or dual point calibration depending of the probes. Basically, the number of points depends of the specific sensor (e.g. the conductivity probe uses a dual point calibration). Below, the steps to for a general calibration (the manual to each probe should be consulted)

1. Turn on the MCU Gateway and IoT element with the specific sensor connected.
2. Navigate through MCU HMI until reach the module that contains the sensor to be calibrated.
3. Pour the calibration solutions in different beakers.
4. Introduce the probe in the first solution (low end value) and wait for a stable output. Make sure that the sensor is completely immersed in the solution and that it is not close to the beaker wall, which may affect the field between the electrodes and disturb the measurement. Once the output is steady, add the real value for measurement and press calibrate button.
5. If the sensor requires a one point calibration, the sensor is calibrated.
6. Otherwise, after getting the sensor from the first solution, carefully rinse it (do not dry the sensor because it could be damaged) and repeat the process explained in step 4 with the second solution (high end value).
7. The sensor is calibrated.

2.5.3.4 MCU Deployment

The MCU deployment consists of two steps: (i) deploy the sensors; and (ii) deploy the IoT Elements and MCU Gateway.

The MCU Gateway should be protected of the weather conditions such as rain and direct sunlight in order to ensure adequate conditions for its operability.

Concerning the deployment of the probes, it is a key factor in the configuration of MCU unit due to the place and the way it affects the setup of the sensors. Below, a few relevant considerations concerning to the probes deployment:

1) The sensors must be completely submerged in the liquid all the time to avoid incorrect metering. Therefore, consider locations where the water volume is variable. If the location where the sensor is going to be deployed does not meet these requirements and it is not possible to find a more proper place it will be necessary to build a protection system to ensure that the sensor is completely immersed and that there is not an airflow disturbing the measurement.
2) The sensors must be installed avoiding the sensing parts are near or in touch with other objects.

For instance, avoid that the membrane of the dissolved oxygen probe touch the tank wall, avoid that the conductivity sensor is close to pump or other devices to not interfere with the sensor magnetic field.

Referring the deployment of the volumetric flow meters, the water entering in them should have a streamlined laminar flow to work properly, turbulent water can cause inaccuracies. Moreover, some installation issues should be considered as water should not be permitted to simply fall out of the flow meter because this would let air enter the device and lead to inaccurate readings.

Once the sensors and probes are deployed, they can be easily attached by just screwing them into the bottom sockets of the IoT elements which must be protected to avoid direct contact with rain and other weather conditions.

2.5.4 Maintenance Requirements

The maintenance procedures of the MCU are mainly focused in the sensors because they suffer wear and tear over time due to its design. Below, the maintenance required for the sensors and how frequently required is described. Moreover, the main evidences to determine a sensor mal-functioning are also presented in the Section 2.5.4.2.

2.5.4.1 Sensors Recalibration

A periodic recalibration of the sensors is highly advisable in order to maintain an accurate measurement along time to correct changes owed to a drift output, polarisation or wear. But, the frequency of the recalibration process will be determined by the accuracy required in the given application, the concrete sensor and the environment in which the sensors will be operating. This recalibration process basically consists in the repetition of the calibration indicated for each sensor in the section 2.5.3.3. The manufacturer of the sensor will indicate the frequency of calibration required for the sensor. Below, Table 12, which lists the sensors and how frequently the maintenance must be carried out on INNOQUA, is introduced. It is important to note that the feedback and experiences obtained throughout the WP4 and WP5 will allow to refine these values depending of the environment.

Table 12: Sensors recalibration

N	Sensor	Time before recalibration
1	pH Probe	~1 year
2	Dissolved Oxygen Probe	~1 year
3	Conductivity Probe	~10 years
4	ORP Probe	~1 year

2.5.4.2 Detection of mal-functioning

The MCU includes tools for an automatic detection of the mal-functioning of the managed sensors and actuators. Nevertheless, there are some indicators that will reveal that a sensor is not working properly. Below, these indicators and their possible solutions are presented:

(a) An abrupt change in the metering. It can be only detected on continuous measurements or measurements with a short time between captures due to non-instantaneous reaction of the sensors. Then, if these leaps are identified, it is probable that there is a sensor problem.
(b) Values out of range. If the measurements of a sensors are out of the normal operation range it will probably be caused by a failure.
(c) A stable continuous metering for a long time. It is very rare that the sensors show a continuous value in a real environment because there are always variations in the water quality. If the measurement is stalled in a given value, the probe will probably be broken.
(d) A lack of a proper response during calibration process such as inconsistent values with the expected output given in section "Calibration Procedure" and never reaching a stable output will be indicatives of a defective of probe.

3 Conclusions

The present document fits into the Work Package 3 Technology integration, eco-design and pre-industrial scale up. This document provides useful information for the construction, maintenance and starting of the prototypes and thereafter for the implementation of the pilot sites to reduce the risks and costs of prototyping.

Input to the present document originates from WP2 with the technical specifications. The present document compiles a description of each individual technology, with specific operational restrictions and requirements, as well as starting procedures and maintenance. The aim of Chapter 2 is to provide detailed information for each technology to minimise start-up and operational errors which might endanger the performance of the units. This was based upon information provided by each technology provider and the results of interviews held with the overall demonstration site lead (ECOIND) and some of the individual demonstration site managers (NBK, SW, BORDA and ECOIND).

The next iteration of this document will feature the integrated systems where the INNOQUA technologies are to be installed in series. Several designs will be provided: the first draft compiles the following options:

- Lumbrifilter → Daphinafilter → BSP → UV
- Lumbrifilter → Daphinafilter → BSP
- Lumbrifilter → Daphinafilter → UV
- Lumbrifilter → BSP
- Lumbrifilter → UV

Both the impact of having the different INNOQUA technologies mixed together and the improvements to the general efficiency of the system will be described and they will impact on the decision making for the pilot construction.

The technology requirements, the risks and issues of integrating these technologies together are to be defined and detailed. Since the effluent to treat will be dependent of the technology appearing previously to the treatment, the range of incoming wastewater specifications for each technology will be once again provided.

The implementation guidelines will feed into WP4 with the aim of optimising the costs for the prototype and at a later stage feed into the prototypes drawings and building of the pilot units.

4 Appendix

4.1 Demonstration Site Manager Interview Results

Key demonstration site managers were interviewed to obtain feedback on site-specific limitations and considerations with regards the maintenance strategies proposed by the technology providers. These have been incorporated into the document, however full results can be found within the following section of the document.

4.1.1 France - Nobatek

Do you know which technologies, and in what combination these will be trailed at your site?

Lumbrifilter and Daphnia

Access?

Good, the site is local to the Nobatek office. However, as much automation as possible is preferable so that we can test if the systems are applicable to other offices (with little to no technical operation) to make it realistic and market ready. Despite this, if needed Nobatek can be reactive to issues as needed.

A decision is required as to whether the systems will be installed over/underground, depending on what would like to be proven/disproved:

i) System totally invisible underground will be better if we are trying to demonstrate an effective treatment system that has low aesthetic impact.

ii) Systems installed over ground would be more useful if the main aim is to demonstrate the technical aspects of the treatment systems.

Lumbrifilter / Lumbricomposting

Visits from the operational/maintenance team will start off daily, then weekly, reduce to monthly gradually, then perhaps annual. This will feed into full scale application inspection requirements. (N.B demo site maintenance likely to be more than full scale application. The specific maintenance requirements are also likely to be different in demonstration trails than in real applications).

Visual inspections – more info needed. Edgar (EUT) will be contacted to discuss what potential sensors and ICT may be utilised for the Lumbrifilter.

For 50PE applications, there are 3 solid/sludge collection points. For 10PE there will be two; a pre-treatment screen and a plastic grid of 5mm at the base of the filter. These will need to be emptied on a monthly basis.

Spray nozzles checks possibly less frequent than monthly. Possibly use specific low maintenance spray nozzle.

3 monthly composting indicates that this process may be too heavily maintenance dependent. This may need to be reviewed. Possibly not realistic for some real applications.

Daphniafilter

Is quantifying daphnia concentrations a high-tech or low tech process? i.e. can the operator undertake this, or would this need to be completed by an external laboratory? For more remote demo sites it may be difficult to undertake this regular. May be easier to monitor parameters that effect numbers than monitor actual numbers. Then monitor numbers less frequently. (Tech provider to identify what parameters affect numbers).

4.1.2 All demonstration sites (including Romania) ECOIND

Do you know which technologies, and it what combination will be trialed at your site?
Lumbrifilter (including lumbricomposting) and Daphniafilter.

Lumbrifilter / Lumbricomposting

Budget may need to be extended for containing lumbricompost etc, though this is not thought to be too excessive – needs to be quantified.

Daily/weekly check will not be an issue in Romania as the demo site is located to treat wastewaters from an ecological building in an easily accessible, non-rural location.

Daphniafilter

Issues with low temperature wastewaters need to be addressed.

Periods of low UV may present some issue with reduced reproduction rates.

Technology may be more applicable as post BSP treatment stage (at demo sites that are trialing both technologies).

How can we check the concentration of daphnia?

Would the daphnia need to be replaced if die off rate high under certain concentrations?

BSP

How is the treatment efficiency related to the VAL? If remove the VAL, maintenance requirements would be significantly reduced. The result however may be that we need to increase reactor size?

Would it be possible to install cheap solar panels to power some bulbs during evening hours to keep processes running and possibly reduce required reactor size?

UV

No anticipated issues

4.1.3 Scotland – SW

Do you know which technologies, and in what combination will be trialed at your site?
Lumbrifilter (including Lumbricompost), daphnia, UV in series.

Lumbrifilter / Lumbricompost

Site visits –

- Week 1 - daily
- Up to end of Month 1 – twice per week
- Up to end of Month 3 – once per week
- Remainder of the trial – monthly

Local operatives will be utilised to operate and maintain the demonstration site trials. They are stationed 24 miles from the site. As a result they can respond to issues as required.

SW would like to assess what is the least human interaction required to achieve maximum effluent quality. To test if the INNOQUA technologies are likely to be market competitive, minimum maintenance and waste production is required. This will be tested during the demonstration site trials.

More information required on sourcing the earthworms.

- Can locally sourced earthworms be utilised
- If non-indigenous earthworms are exposed to the environment, may this present an ecological issue

Daphniafilter

More information required on sourcing the Daphnia.

- Can locally sourced daphnia be utilised
- If non-indigenous daphnia is exposed to the environment, may this present an ecological issue

The maintenance schedule states that the operating temperatures of the daphniafilter are 6-26°C. Wasterwater temperatures are typically around 13oC, however during winter months, might this be an issues? Could this be resolved by introducing trace heating?

UV

No potential issues foreseen. UV lamp technology is already utilised for some coastal discharge locations in Scotland.

4.1.4 India – BORDA

Do you know which technologies, and in what combination these will be trailed at your site?

Lumbrifilter and Dapnifilter. Maybe some other technologies, however, it is not clear yet.

Tatjana will be there for the whole trial duration of 1 year. Also, other technicians will be on site. Most likely, every day somebody will take care of the trial.

Lumbrifilter

All the maintenance requirements seem feasible. However, hands on experience is required for the practicality of these tasks.

The power outage is quite common in India. It is not clear how it effects the operation of the INNOQUA system. Re-start manual should be available for this reason.

Daphniafilter

There are concern about the viability of efficiency of daphniafilter as temperate in India is over 35-36 °C during summer. Also the frequency of the maintenance and the maintenance tasks may be problematic.

Sampling, measurement and maintenance manual should be provided.

BSP

It seems OK. No major comments and concern here.

No information about the required hours of sunlight and intensity. Both significantly varies during the year.

Can microalgae overgrowth be a problem?