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D5.3 – Lessons from the Demonstration Sites

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Abbreviations and Acronyms

AquaEnviro	AquaEnviro/SUEZ - Project Partner
BORDA	Bremen Overseas Research and Development Association - Project Partner
BUV	Berson Milieutechniek BV - Project Partner
DoA	Description of Activities
DE5	DE5 Services SRL - Project Partner
EUT	Fundacio EURECAT - Project Partner
GYA	Yepez Madrunero Grace - Project Partner
LBT	Lombritek Association - Project Partner
NBK	Nobatek - Project Partner
NUI Galway	National University of Ireland Galway - Project Partner
EKO	Ekodenge - Project Partner
ECOIND	Institutul National De Cercetare Dezvoltare Pentru Ecologie Industriala - Project Partner
REDI	Redi
RMC	RITMIC Com SRL - Project Partner
INB	Inbrool Industries SL - Project Partner
SW	Scottish Water - Project Partner
TPWG	Technology Prototyping Working Group
UCU	Universidad De Cuenca - Project Partner
UCSM	Universidad Catolica De Santa Maria - Project Partner
UDG	University of Girona - Project Partner
WRF	Water Research Facility
WWT	Wastewater Treatment

Executive Summary

Contaminated water from inadequate waste water management poses one of the greatest health challenges as it restricts social and economic development, increases poverty through costs to health care and endangers the environment (UNEP, 2010).

The aim of the INNOQUA Project is to progress, towards commercialisation, the development of a fully ecological modular sanitation system that integrates individual low cost, sustainable and biologically based technologies. The system will offer flexible waste water treatment solutions to suit a variety of target markets in developed and developing countries.

This report, Deliverable 5.3 (D5.3) presents details of the lessons learned from installation at the Project's demonstration sites.

From information provided by the INNOQUA Partners, D5.3 follows sequentially the experience of INNOQUA Site Managers at the 11 Demonstration Sites and 2 Prototype Sites from planning to operation and maintenance. This report Deliverable comprises following sections:

- **Planning and Advance Works**
- **Site Installation and Initial Setup**
- **System Startup and Commissioning**
- **System Operation**
- **System Maintenance**
- **Applying the Lessons**

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 summaries the experience of the Demonstration and Prototype Site Managers from Planning to Operation and Maintenance of the INNOQUA System on site.

1.1 Work Package 5 Objectives

A key step in the exploitation of new technology in the water and wastewater sectors is the design, installation and operation of prototype technologies under real conditions at a number of key demonstrations sites. The demonstration sites activities of WP5 allow for prototype/market ready versions of various technologies to be trialled.

The principle objectives of WP5 as listed in the Grant Agreement are as follows:

- Develop full scale demonstration prototypes featuring for each of the target market a scenario identified, putting real scale/ real-operation conditions (including local technology assessment, social acceptance and marketing conditions).
- Design and deploy ICT systems and relevant remote sensing capability to each of the demonstration units in the pilot sites countries.
- Fully test performance of the aforementioned prototypes to include treatment performance, energy analysis, operational and maintenance analysis and long term sustainability.
- Engagement with stakeholders and end-users to refine technology design, operation and maintenance.
- Host open days for stakeholders to view the technologies in action on-site.
- Document and synthesize all results.
- Preparation of technology guideline documents and specifications for commercial exploitation.

1.2 The Role of Deliverable D5.3

The role of D5.3 Lessons from the Demonstration Sites is to document and assess the experience from the demonstration activities in terms of the technical installation, operation and maintenance activities and the experience in terms of any societal impact or engagement. These lessons will be used to inform strategies in terms of addressing potential markets.

T5.2 and this output, D5.3, have a critical role in the project development facilitating the compilation and assessment of the experience of users in a real-world application of the INNOQUA technologies to improve and strengthen the final market offering.

Figure 1-1 following shows the interdependencies and relationships between project work packages as they relate to WP5 and Deliverable D5.3.

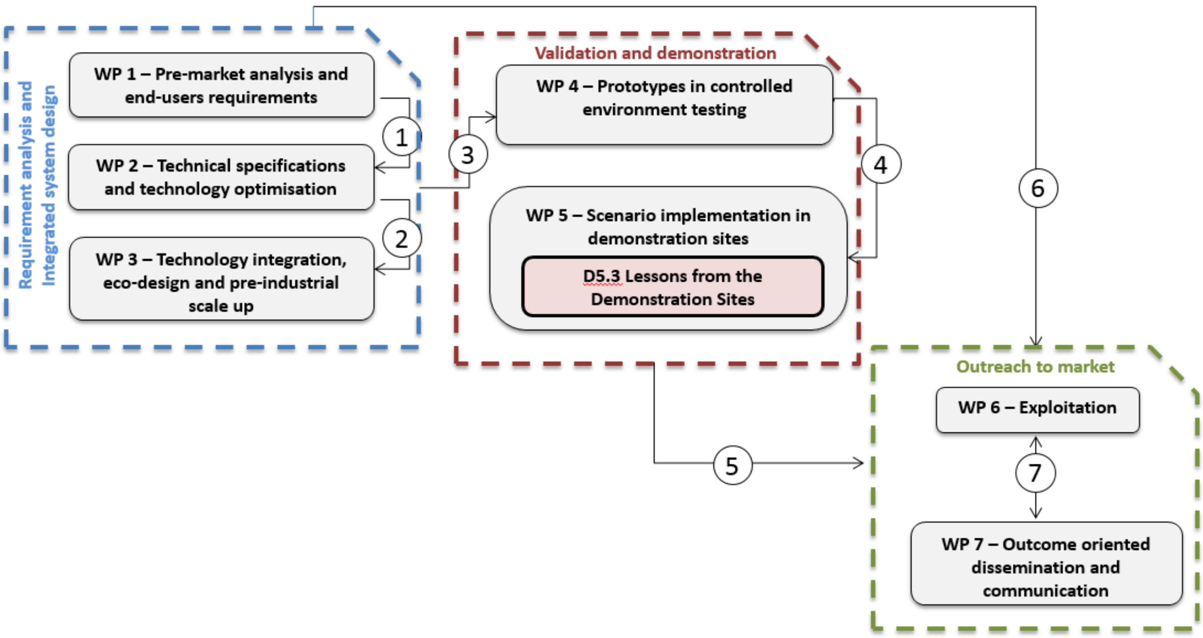


Figure 1-1 Relationship of Deliverable D5.3 to Project Activities

1.3 Approach to Deliverable Development

To comprehensively document the experiences of Demonstration Site Managing Partners from their Demonstration Sites, the process from planning to operation and maintenance was considered in 5 distinct steps as indicated in Figure 1-2 below.

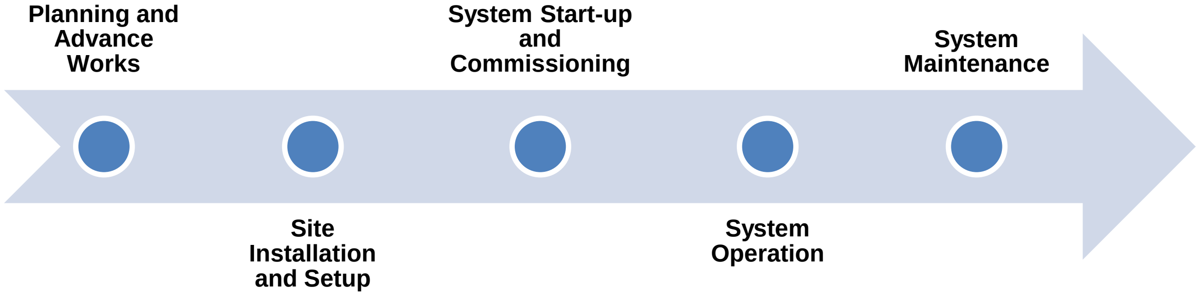


Figure 1-2 Demonstration Site Implementation Process

A detailed questionnaire was then circulated to each of the demonstration and prototype site managers to record their experience at each the stages. The questionnaires were completed between January 2020 and March 2020.

This Deliverable follows the process stages described in Figure 1-2.

1.4 Document Outline

In particular, this document provides key information to inform the integrated INNOQUA Technology in the following Chapters;

Chapter 2 – Describes the planning and advanced works undertaken at each of the demonstration sites focusing on the work undertaken before the INNOQUA system arrived at the site.

Chapter 3 – Describes the activities undertaken to secure delivery of the INNOQUA System to site and the work carried out in advance of start-up

Chapter 4 - Describes the experience at the demonstration sites in starting the INNOQUA system and commissioning its operation.

Chapter 5 - Outlines the experience at the demonstration sites in operating the INNOQUA System in the early days until Steady-State operation is reached

Chapter 6 – Describes the maintenance activities at the demonstration sites and the routines maintenance programme followed.

Chapter 7 – Provides a summary of the preceding Chapter findings and considers how the Lessons Learned will be used.

1.5 The Demonstration and Prototype Sites

Table 1-1 below describes the INNOQUA Demonstration and Prototypes Sites, the sources of water that will be received by the INNOQUA system on the sites and the intended reuse of the water.

Table 1-1 Summary of Demonstration and Prototype Sites

	Country	Source of wastewater	Water Reuse?	Proposed reuse
Demonstration Sites				
1	**Ireland**	Dairy and beef farm	Yes	Agricultural land or yard cleaning
2	**France (LBT)**	Aquaculture facility	No	-
3	**Italy**	Domestic dwelling	No	-
4	**France (NBK)**	Offices	No	
5	**UK**	Domestic dwellings	No	-
6	**Turkey**	Domestic dwellings and offices	Yes	Irrigation of ornamental plants
7	**Romania**	Tourist Pension and restaurant/ Office building (since 01.10.2019)	No	-

8	**Ecuador**	Domestic apartment complex	Yes	Irrigation of ornamental plants
9	**Peru**	Educational institution	Yes	Irrigation of ediblecrop
10	**Tanzania**	Domestic dwellings	Yes	Irrigation of banana plantation
11	**India**	Domestic dwellings	Yes	Irrigation of edible crops
	Prototype Sites			
1	**Ireland**	Research facility – Municipal Wastewater	No	Investigation of Reuse Potential
2	**Spain**	Research facility – Municipal Wastewater	No	Investigation of Reuse Potential

The INNOQUA Technologies comprising a fully adaptable modular solution are indicated schematically in Figure 1-3Figure 1-1 below. The operation of each technology is fully described in other Project Deliverables in particular D5.1 and their application at the Demonstration Sites is described in D5.1 and D5.2.

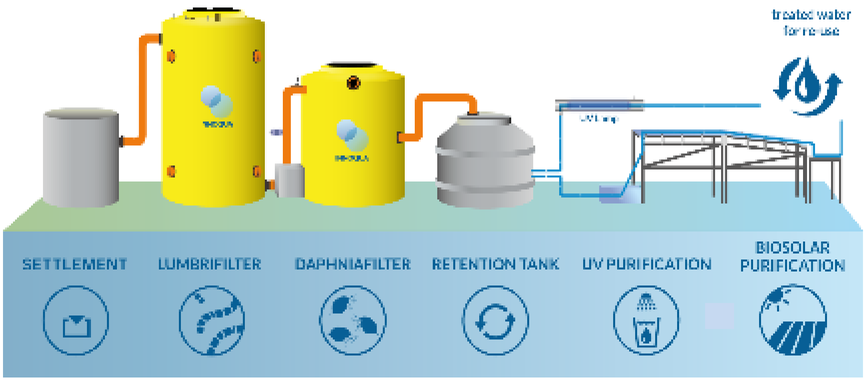


Figure 1-3 The INNOQUA Technologies

Table 1-2 below shows the technology configuration installed at each of the Demonstration and Prototype Sites.

Table 1-2 INNOQUA Technology Configuration at each Site

Country	INNOQUA Technology Configuration
Demonstration Sites	
Ireland	Lumbrifilter
France (A)	Lumbrifilter + Daphniafilter
Italy	Lumbrifilter + UV
France (B)	Lumbricomposting

UK/Scotland	Lumbrifilter + Daphniafilter
Turkey	Lumbrifilter + Daphniafilter + UV
Romania	Lumbrifilter + Daphniafilter
Ecuador	Lumbrifilter
Peru	Lumbrifilter + Daphniafilter + UV & Lumbrifilter + BSP
Tanzania	Lumbrifilter + Daphniafilter + UV
India	Lumbrifilter + Daphniafilter + UV & Lumbrifilter + BSP
Prototype Sites	
Ireland	Lumbrifilter + Daphniafilter + UV
Spain	Lumbrifilter + Daphniafilter + UV & Lumbrifilter+ BSP

2 Planning and Advance Works

This first stage of the Demonstration Site Implementation considers the planning and any necessary permissions and approval etc that were required to allow the Demonstration site to proceed as planned. The following sections review the information provided by each of the sites in answer to a series of comprehensive questions to relating to planning and advance works, each section is preceded by the question asked to the demo site managers.
Information below is based on information received from the following demonstration sites numbered 1, 2, 3, 4, 6, 8, 9, 10 and 11 and Prototype Sites 1 and 2 in in Table 1-1.

2.1 Identifying the Demonstration Site

Question: Briefly describe the demonstration site, the INNOQUA System(s) Installed and location (comment on any changes from the information provided in Deliverable 2.1)

Both of the prototype sites and the majority of demonstration sites were established as planned and as described in the WP 2 Deliverable D2.1. The notable exception is the Tanzanian Demonstration Site and the Indian Demonstration Site. The Tanzanian site was originally planned to be located at Uhai wa mazingira na watu (UMAWA) Faecal Sludge Treatment Plant, Dar es Salaam, Tanzania, Africa to treat wastewater from Domestic Housing and at training centre/ meeting hall facility (for 20 -30 participants). The site was installed at Mlalakua Faecal Sludge Treatment Plant (FSTP) is located in the district of Kinondoni, Makongo. The demonstration site treats wastewater of 4 households comprising 37 people approx. The Indian Demonstration Site was built where originally planned, at the Beedi Workers Colony, however the location within the site was revised.

Question: Briefly Describe the Main Issues that led to the choice of Demonstration Site

In general, the demonstration sites were chosen as they are each representative of a potential market but the availability and accessibility of the sites were factors affecting the site selection. The NUI Galway Agricultural Demonstration Site at Kilquain, Craughwell County Galway was selected as it fulfilled the requirement of being a fully operational dairy farm of significant size (100 cows) but was also in close proximity of NUI Galway. In the original Grant Agreement an alternative site was proposed at an agricultural research facility in County Cork, 180km from NUI Galway.
The French Demonstration Site at Anglet was chosen mainly because this site is on a private site and located next to the public sewage network. Moreover, a concrete slab was already present,unused and ata suitable level based for the system tanks.
The Italian demonstration site was chosen as it represents a new build located in an area of ‘protected landscape’ but without access to a centralized wastewater treatment system.
The Aquaculture site at La Canourgue, France was selected as the INNOQUA Lumbricomposting site as it is an aquaculture education facility and fish farm. Aquaculture sludge management is a major issue for fish farming facilities. By locating the lumbricomposting facility onsite, waste aquaculture sludge is transformed to a compost product on site.
The Scottish Demonstration Site at Littlemill site was selected to allow the technology to be tested in a wide range of weather conditions. Also, the existing arrangements enabled the effluent from the

INNOQUA plant to be returned to the head of the existing treatment process, eliminating environmental constraints related to discharge requirements.

The Turkish Demonstration Site was located in Sinop as in addition to meeting with the project requirements, the area has a number of de-centralized residential sites that would fit for project exploitation purposes.

Only approx. 56 % of Romanian population is connected to a wastewater collection and treatment system. Most of the people lacking proper sanitation are located in the rural areas. The Romanian demo-site was designed to serve a small multi-user building (touristic application) located in the rural area of Suceava thus targeting Eastern Europe less deserved areas.

Ecuador has a low level of wastewater treatment (around 10%) and Quito only treats 3% of its wastewater. At the location of the Ecuadorian Demonstration Site at Quito, at high altitude 2,800m alt, pollution is generated very close to water sources and polluted water is then used, mainly for agricultural purpose. Quito also has financial constraints to finance large treatment wastewater infrastructure so the INNOQUA solution is relevant as an alternative.

In Tanzania, the Mlalakuwa FSTP owned and operated by BORDA was selected as the most appropriated demonstration site due to land availability, constant production of wastewater and the existence of a MoU signed with the Local Government Authorities to use the treatment site as a research center.

The Indian Demonstration site is directly located at the NGO Consortium for DEWATS Dissemination (CDD) office, with long-term relation to the community and a collaboration with Borda. The low-income community at the complex was only partially connected to a wastewater treatment facility and commonly open drains were observed. CDD Society together with BORDA had a similar NEXUS Project at the given location. In this project public health, water insecurity and food insecurity concerns were observed. The land was given by the community for the project implementation.

The Prototype sites at Tuam Water Research Facility, Galway, Ireland and Quart Water Research Facility, Girona, Spain were key controlled prototyping facilities managed by project partners NUI Galway and University of Girona to validate and optimize the INNOQUA Solution.

2.2 Planning and Location

Question: Did the selected demonstration site location necessitate any planning or permits? Describe Lessons Learned regarding the obtaining Demonstration Site planning or permits?

Formal permits/permissions were in general not required at most of the demonstration sites however in the case of the Lumbricomposting facility La Canourgue, planning permission was required for the lumbricomposting shed due to its size and the heritage designation of the area. In the case of the Italian Demonstration Site, a number of permits were required as the demonstrator is part of a new residential build in a landscape protected area, the permit associated with the wastewater from the INNOQUA system specifically is the "discharge permit" which is issued by the Abruzzo Regional Authority. At the Scottish demonstration site, permission was required from the Highland Council and a consultation with local public was also required, this led to minor change in location of the originally installation to avoid impact on trees. In Romania, full technical documentation was requested by the local authorities (Llisesti City Hall) to issue the construction authorization for the biofilter room (insulated sandwich panels on metallic structure) that was built to host the INNOQUA

System. In Tanzania, the requirement was averted due to the existence of an existing MOU. Permission from the community was required at the Indian Demonstration Site.

At the Prototype Sites, the facilities are both on sites of municipal plants but operate as closed systems permission to install was gained by notification to the municipal plant operator in the case of Ireland and similarly for the Spanish prototype site.

2.3 Pre installation Site Works

Question: What works were necessary in advance of the installation of the INNOQUA System at the Site? Briefly Describe Lessons Learned regarding advance works necessary at the Demonstration Site

Of the sites assessed, all with the exception of the site at Sinop, Turkey, required pre-installation works to be carried out. The most common pre installation works required the provision of additional pipework, pumping stations and access chambers as well as electrical supplies at the demonstration sites as well as suitable level (generally concrete) plinths to take the installations. In Italy, a dedicated room was designed and constructed at the residential property that is the demonstrator to house the INNOQUA System and the control panel etc. In the case of Quito, Ecuador separation of the rainwater and wastewater was required at the site and in the case of Tanzania a pit and shelter for the daphniafilter was required but the availability of contractors, the temperature extremes that limit working hours and the availability of building materials all posed challenges to the completion of the works at the site in Tanzania. The works required at the Peruvian Demonstration Site were complicated by lack of information regarding existing utilities. At the Scottish demonstration site, the INNOQUA installation was constructed on a moveable platform (skid) which served to limit time on site to complete pre-installation works. In Romania, since temperature conditions usually reach -25^{0}C during winter time, usual installation of wastewater treatment facilities are accommodated in the underground, however, since it was plan use the demo-site as a demonstratorand a dissemination platform, a dedicated insulated room has been build to ensure similar temperature conditions to an underground option.

Figure 2-1 INNOQUA Installation at Littlemill, Scotland

2.4 Stakeholder Engagement

Question: List any key stakeholders that were identified in advance of works. Briefly describe Lessons Learned regarding stakeholder identification and classification. Describe any stakeholder engagement that was conducted in advance of work commencing. Briefly describe Lessons Learned regarding early stakeholder engagement.

The identification and engagement of stakeholders i.e. those who can affect or be affected by a Demonstration Site installation and operation is particularly important in a community setting. Where the demonstration site is installed on private property with limited exposure to local community the process is simpler. In these situations, e.g. at the Agricultural Demonstration site in Ireland, once permission for the installation from the landowner was received and the scope of the work defined and agreed the project could proceed with regular communication with the landowner on issues if or as they arise. Attention can then be focused to stakeholders who may be interested in the project from a future adoption or promotion perspective.

In the case of the community-based demonstration sites in Scotland, Tanzania and India the situation is very different and the importance of a comprehensive stakeholder engagement strategy is validated. Scottish Water (SW) as a utility company have a significant expertise in this area and had meetings with key stakeholders such as the EPA, SW Operations teams, the Highland Council and local residents to identify issues pre planning. These consultations proved invaluable ultimately avoided planning objections as residents' concerns regarding expected negative visual were addressed early.

In the case of Tanzania, the lack of early stakeholder identification and engagement had a significant negative impact on the local acceptance of the demonstration site. The complex socio-economic landscape at the informal settlements of Dar es Salaam, Tanzania make the engagement with several influential members of the community as well as the Local Government Authorities officials and local leaders a very important aspect of any new development. In particular with wastewater treatment systems in low-income communities in Tanzania where people are extremely sensitive to topics such as wastewater management which is often associated with bad smell and illnesses.

Early in the Demonstration Site Operation, problems arose in the community due to the smell of the system during the dosing periods. The Demonstration Site Manager believes that this situation could potentially have been avoided if a community awareness event (specifically neighbours of the treatment site and most important old people) had taken place before the installation of the INNOQUA system where these possible problems would have been explained.

In the case of the Indian demonstration site efforts to engage with the community office were made very early on in the project, however the community office is poorly resourced and this impacted its ability to disseminate the information. The Demonstration Site Manager from the Indian site commented that most community members are not familiar with the processes/relevance of wastewater treatment and that a wastewater unit directly located in the community is a sensitive topic.

2.5 Lessons Learned

In selecting the sites, the experience from the demonstration sites concluded that;

2.5.1 Identifying the Demonstration Site

- When the site is located a great distance from the demonstration site management team (in the case of Scotland, a 3.5-hour drive) this presented some challenges for sampling and maintenance.
- The availability of wastewater to maintain the biological system was a challenge in low occupancy housing e.g. Sinop, Turkey. However, temporary lack of influent (e.g. during the weekend or holidays for the demo-site in France serving an office building) had a limited impact on the performance of the system and biological viability of the system.
- In a very restricted site in close proximity to the housing and offices served by the INNOQUA system, solution e.g. in Ecuador, solutions were developed to optimize tanks to fit the site and eliminate odours. Difficulties with the daphniafilter operation at the site led to the revision of the daphniafilter tank to function as a second lumbrifilter tank. In addition, the system at Quito provided a model for a fully locally sourced system.
- In unplanned settlements characterised by extremely low incomes and lack of availability of very basis needs including water and power, such as at the Tanzanian Demonstration Site, wastewater treatment is not a priority. The hierarchy of needs in such low income communities, highlighted the issue that in such communities, benefits such as wastewater treatment are not sufficient for social acceptance of a new system. It was concluded that it would have been preferably to install the INNOQUA solution at a hotel, embassy or boarding school where the treatment of wastewater is more of a priority and considerably

expenditure is already allocated to sludge collection.

2.5.2 Planning and Location

- In the case of permits and or permissions, where required, it is important to identify this early and to allow sufficient time for the process to be conducted.

2.5.3 Pre installation Site Works

To limit the impact of pre installation works, it is preferable that the installation of the INNOQUA system be accommodated at planning stage of a new build.
When external contractors are required to carry out works, it is advisable that a number (at least 3) quotations are sought as there can be significant variation in quotations received.
The pre-installation works should be well planned by suitably qualified and experienced personnel to optimise the works and reduce impact on the site.

2.5.4 Stakeholder Engagement

Early stakeholder identification and engagement is a key aspect of the successful progress of a project particularly in a community setting.
Preliminary workshops before installation are required to involve communities in the process to install a treatment system also to inform on benefits of sanitation, strengthen ownership and ensure social acceptance.

3 Site Installation and Initial Setup

This stage of the Demonstration Site Implementation includes arrival onsite of the INNOQUA System components and their installation.

The list below briefly describes the list of INNOQUA system components and their source:

- Daphniafilter and Lumbrifilter tanks – designed within the consortium for each demo-site and manufactured and delivered by REDI (project partner) and in the case of the prototype units at NUI Galway and UdG, manufactured and delivered under the direction of Inbrooll (project partner)
- BSP platform reactors – designed within the consortium and built on-site by ECOIND and NOBATEK with locally sourced materials and support from BORDA (in India) and UCSM (in Peru)
- UV system – designed constructed and delivered to dedicated demo-sites by Berson UV (project partner)
- MCU unit - designed, integrated and delivered to all demo-sites by EURECAT (project partner)
- All other ancillary components, materials required and biologic inoculums were sourced locally by each demo-site manager.

The following sections review the information provided by each of the sites in answer to a series of comprehensive questions relating to this element of the works, each section is preceded by the question asked to the demo site managers.

Information below is based on information received from the following demonstration sites numbered 1, 2, 3, 4, 6, 7, 8, 9, 10 and 11 and Prototype Sites 1 and 2 in in Table 1-1.

3.1 Transportation and Arrival onsite

Briefly describe the transportation, delivery and arrival on site of the INNOQUA system components

The delivery of the tanks to site required a suitable vehicle that could be accessed by a forklift or that was fitted with a lifting arm/crane. The practice by many delivery companies of subcontracting deliveries caused an issue at the Irish prototype where the tank first arrived in an undersized truck with no access for forklift and not fitted with a crane. The situation necessitated return of the container to the port of arrival and reload to a suitable truck. Tank delivery to the agricultural demonstration site, Scotland and Italy all involved an intermediate delivery to a depot or similar and then onward transport in a truck with a suitable lifting device. Transportation and delivery of all equipment from Europe to Ecuador, Peru, India and Tanzania suffered lengthy delays due and difficulties due to permits, customs duty, taxes and procedural issues. This process was extremely time consuming for the demonstration site managers in these countries and additional costs were incurred; delays of up to 3 months (in the case of Tanzania) were encountered. Some transport damage was also reported on the daphnia tank sent to Peru and the lumbrifilter tank that arrived to Ireland at the Agricultural Site.

Figure 3-1 Arrival of tanks at Romanian demo-site

3.2 Enabling Works

Briefly describe any works (mechanical, electrical, civil) that were required onsite to connect the INNOQUA system in advance of Installation and any works relating to the provision of utilities such as power, water and data.

The provision of a level stone surface at the Irish Agricultural site was required as was the installation of an electrical control panel to connect the required pumping etc and pipework to direct influent wastewater from the dairy parlour sump. A pump sump (tank with pump preinstalled) and maintained above surface reduced the works onsite considerably. A PLC control system was installed in the control panel before delivery to site. The electrical work was carried out by a registered electrician and the pipework and civil work by the INNOQUA Team. At the French Demonstration Site (Nobatek Offices) pipework and electrical connection by a registered electrical contractor were required. In the case of the Italian Demonstration Site, a dedicated room with a reinforced concrete floor was constructed to house the INNOQUA system, this was equipped with electrical power and a water supply and the necessary influent and effluent pipework. In Romania, due to low temperature conditions during winter season, a special insulated room on a metallic structure with sandwich panels was built to host the system. Authorised contractors were hired to build the biofilter room and to perform the electrical works while the installation of the pumping station, pipework and civil works were performed by the INNOQUA team.

Construction of the INNOQUA system on a movable platform, limited on site works to the provision of concrete footings to receive the structure, water and power were available on site and connections were made by a contractor. Considerable excavation and the provision of a concrete slab was required at the compact Ecuadorian Demonstration Site. In Peru, considerable enabling works were necessary to provide a covered concrete platform for the INNOQUA system onsite and access to power, water and the necessary necessary pipework. In Tanzania, electrical and instrumentation work was required to establish the INNOQUA system on site and difficulties were encountered with the MCU as a control device. The possibility of vandalism, theft and frequently power outages complicated the installation onsite. A power backup system was required also. In India, difficulties with power supply also required provision of back up supply to the new connection that was required. Pipework and civil work for the connection to the system was complicated by inaccurate existing plans and uncertainties with the standard of new installed works.

At the NUI Galway Prototype Site, a specialist contractor was engaged to carry out pipework, electrical installation, control panel and minor civil works required for the INNOQUA System. The control of the system is by a PLC. A new power supply and electrical control cabinet was installed at the site. New power supply, concrete platform and pipework were required at the UdG Prototype Site.

What works were necessary onsite to complete the installation and setup of the INNOQUA System?

In addition to the pipework, pumping and electrical controls that were required to finalise the setup of the INNOQUA system on site, some sites installed fencing and screening i.e. in the case of France Office demonstration site and at the residential/office site in Quito to better integrate the system into an established setting. In the case of Tanzania, all manholes needed to be covered with a steel mesh and a padlock to avoid vandalism and theft. Also, at this site a cage was built to protect the backup power supply system and the UV lamp to protect against theft. In Scotland insulation of pipework was necessary due to the low temperatures experienced at the site.

Figure 3-2 Timber Screening at the Lumbrifilter System Quito, Ecuador

In the case of the insulated lumbrifilter tanks provided at the Irish Agricultural and Scottish Demonstration Site, work was needed to waterproof the tanks as the design did not prevent the ingress of rainwater via the lid or at the pipe openings to the insulation layer between the plastic yellow tank and the aluminium casing.

Filling of the lumbrifilter with granular material and the active layer material was required at all sites and access the top of the lumbrifilter to carry out this activity was generally gained by purchase of a small mobile platform for use at the sites. In the case of the large diameter tank (2.45m diameter) at the NUI Galway Prototype Site that was constructed to the 10 p.e. prototype design data 17/01/2018, a crane was required to lift the lid on and off of the tank to complete any largescale filling and such operations. Routine operations at the tank were made possible by the 4 access hatches in the lid.

Some demonstration sites e.g. Irish Agricultural Site replaced the spray mechanism for dosing the wastewater onto the active layer with a splash plate before system start up, see below. This action was taken based on the expected high level of solids at the agricultural site and the experience at the NUI Galway Prototype Site with clogging in the perforated pipe dosing mechanism when dealing with high solids.

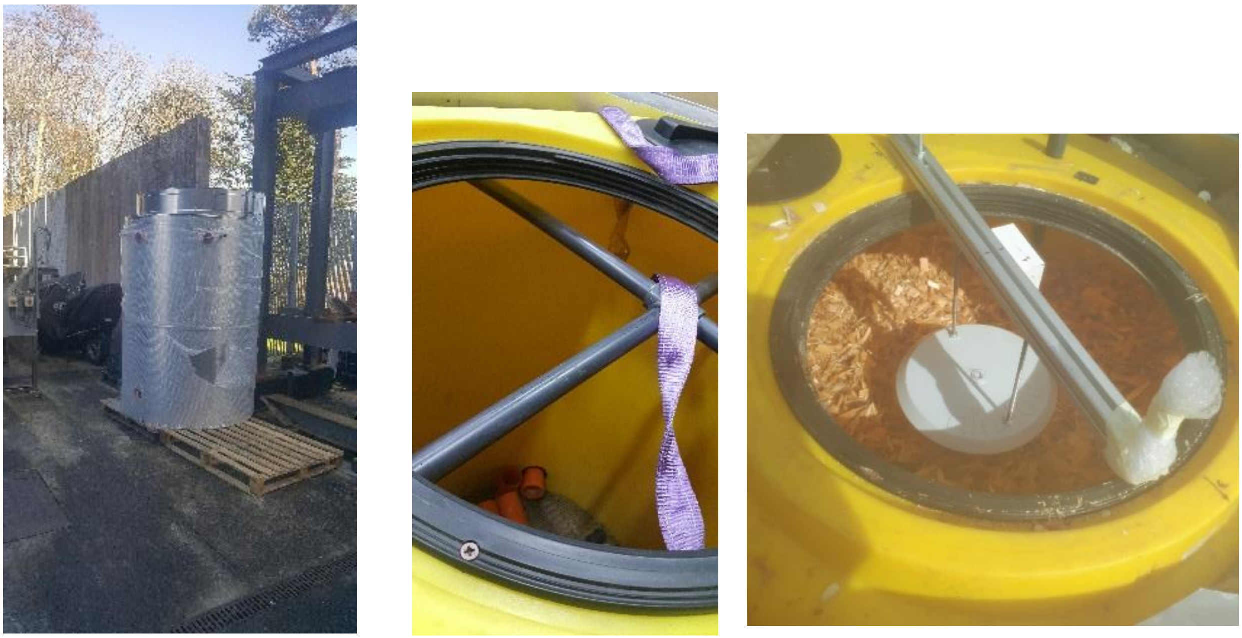


Figure 3-3 Lumbrifilter Arrival at NUI Galway (a) Initial Perforated Dosing Mechanism (b) and Revised Splash Plate Dosing Mechanism (c)

In the case of the daphniafilter installation, connection of pipework and filling of the system were the main tasks required on site to complete installation. At the NUI Galway prototype site, a venturi valve was assembled by the project team for installation at the sire. At the Tanzanian site, the daphniafilter was placed below ground to allow gravity feed from the lumbrifilter and was protected by a shelter to avoid the incidence of direct sunshine.

The MCU in all cases required connection of probes to the IoT entities, a stable internet connection for the gateway and suitable power supplies for the Gateway and each of the IoTs and installation of the above in suitably rated weather proof boxes. All these actions along with additional works of integrating pump control relays and additional inputs to be measured and logged (e.g. from flowmeters) generally required a suitably qualified/skilled electrical/automation contractor to complete. In the case of the Peruvian and Romanian demonstration site a fixed internet connection was required as the wireless/mobile connection was not strong enough. For the Romanian demo-site, the distance between MCU gateway and the IoT gathering data from the sensors in influent was very high (~ 40 m) causing miscommunication forcing us to reposition the IoT (outside of the weatherproof metallic box which was screening the signal).

The UV system installation at the prototype and demonstration sites required for outdoor installation and the construction/provision of an enclosure to protect against the elements, the photos below show the UV system on arrival to Galway and the enclosure purchased locally and adapted to fit the system by the NUI Galway project team.

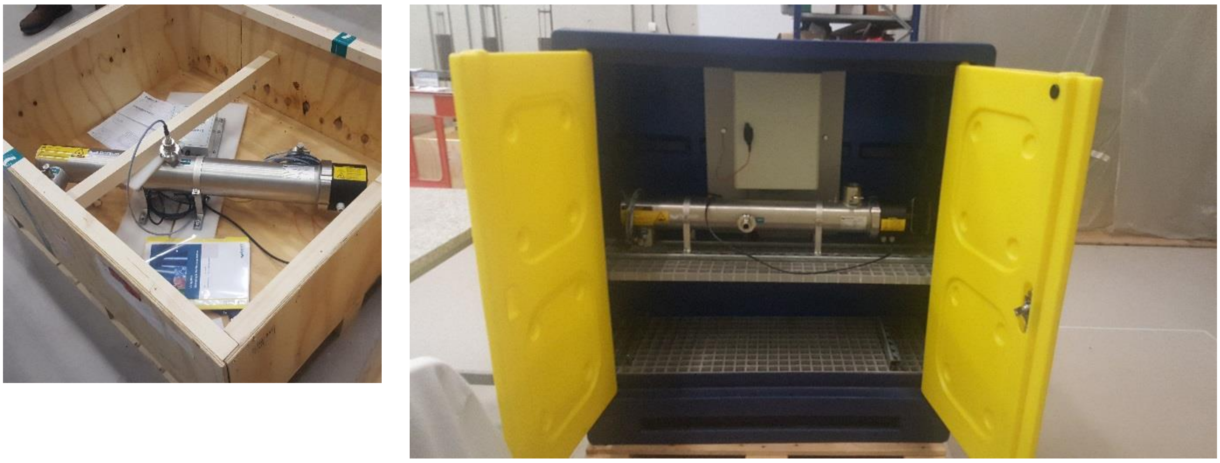


Figure 3-4 UV System Arrival at NUI Galway and Installation in Locally Sourced Cabinet

The BSP was subject to redesign over the course of the project mainly due to the desire to reduce the costs of production and operation of the BSP module and also due to the withdrawal from the project of the project partner, Heliopur Technologies. Local fabrication was engaged in all cases to complete the system to the design prepared by the INNOQUA Project team.

Figure 3-5 India on site manufacturing of the BSP module by the INNOQUA project team

3.3 Sourcing Materials and Ancillary Components

Describe how/where necessary materials (tanks, pipework etc), ancillary components (meters, sprinkler systems, pumps, woodchips, coconut husks etc) required for the INNOQUA system were sourced?

For all demonstration sites the main lumbrifilter and daphniafilter tanks were provided by the Project Partner Redi and transported to the demonstration sites. In the case of the NUI Galway and UdG Prototype sites, these tanks were designed by the INNOQUA team and manufactured by a Spanish Company under the direction of the Project Partner Imbrooll.

The holding tanks and pipework were in general locally sourced at building supply stores or markets. In Ireland and Scotland, an external contractor was engaged to supply and install the pipework, pumps and electrical components which made this aspect of installation completion more efficient. In some countries, i.e. Ecuador and Tanzania, sourcing pipework and pumps to the specification required by the INNOQUA system provided very difficult and led to a pump being sourced in France for the Ecuadorian demonstration site and Kenya for the Tanzanian site. Smaller ancillary items required such as bars and plates to make the splash plate are available locally but costs are substantial relative to the local income levels.

3.4 Sourcing Biological Components

Describe how/where necessary materials and biological materials (earthworms, daphnia etc) required for the INNOQUA system were sourced?

Sourcing of the recommended earthworm type (*Eisenia fetida)* proved to be difficult in Ireland and the worms of the NUI Galway prototype site were imported from the UK. An alternative earthworm variety (*Dendrobaena veneta*) also common used in composting was found to be available in Ireland and laboratory studies carried out at NUI Galway showed that the performance of the the locally sourced worm variety is comparable with that of the imported worm so the locally sourced worm was used in the agricultural demonstration site. In Tanzania, the earthworms of type *Eisenia fetida* were imported from Kenya and incurred considerable costs in terms of taxes and transportation for what should be a low cost item. Later a similar alternative earthworm variety, *Eudrilus eugeniae*, was identified as a potential alternative more readily available and low cost. Some demonstration sites, e.g. France and Peru bred the earthworms at the site while most other sites (Romania, Italy, India, Ecuador, Turkey, Scotland, Spain) procured the earthworms *Eisenia andrei* or *Eisenia fetida* from local suppliers (which were usually breeding them for composting applications).

In Ireland, woodchip was easily sourced (soft wood not hardwood as originally recommended) as this is a by-product or waste product and was provided free of charge for collection from a local timber manufacturer. In Romania, hardwood woodchips were easily sourced since the Romanian partner RITMIC is active in the timber industry and has the possibility of making woodchips, however, having them in the appropriate size required manual sorting and sieving. In other countries such as Ecuador, Peru, Tanzania and India, sourcing of woodchip proved more challenging. Coconut chips/husk chips were used as an alternative to woodchip in India, Tanzania and Ecuador. In Peru wood shavings were used as material for the active layer since it was hard to find woodchips. In Tanzania, the use of coconut husks caused additional problems with local residents as the material induced a brownish colouration of the effluent and this resulted in a negative impression for local neighbours interested in the performance of the system. To address this, the coconut husks were replaced by woodchip sourced some 200km from the site. This resulted in additional expenditure in terms of purchase, transport and road taxes.

The sourcing and breeding of *Daphia sp*. *(magna, pullex, etc)* proved a challenge at many of the demonstration sites, in Ireland, the sourcing of live daphnia was uncertain as limited availability and efforts to breed from an initial supply from aquatic supply shop proved unsuccessful. In Romania, Daphnia were hatched and bred successfully in laboratory starting from *Daphnia magna* epipheea supplied within the Daphnia toxicity kit. However, once transferred to the site the batches were lost and additional breedings and adaptation of daphnias to the LF effluent were trialled. In Peru, initially daphnias were sourced from the local river and bred in laboratory while later daphnia inocullum were provided by local suppliers. In Tanzania, it was difficult to find *Daphnia* in Dar es Salaam. Most of the streams (lakes, rivers, lagoons, etc) are extremely polluted making difficult for *Daphnia* species to survive. For the first 6 months, several liters of *D. magna* were imported from Germany, but after few days of being in Dar es Salaam the population perished. A cladocera species was discovered in a wetland area and although not part of the Daphnia family, they also have a filter feeding system similar to Daphnids, so they were used as a viable alternative. The presence of several mosquito larvae and tadpole in the daphniafilter was a problem and a mosquito net was provided on the top of the Daphniafilter to prevent the breeding of mosquito and potential spread of malaria which is a major concern in Tanzania context.

The microalgae used for inoculation of the BSP systems were indigenous species procured from nearby surface waters (lake, ponds), biofilm created on the inside of the Indian LF walls or even lab scale cultures (Chlorella, Scenedesmus).

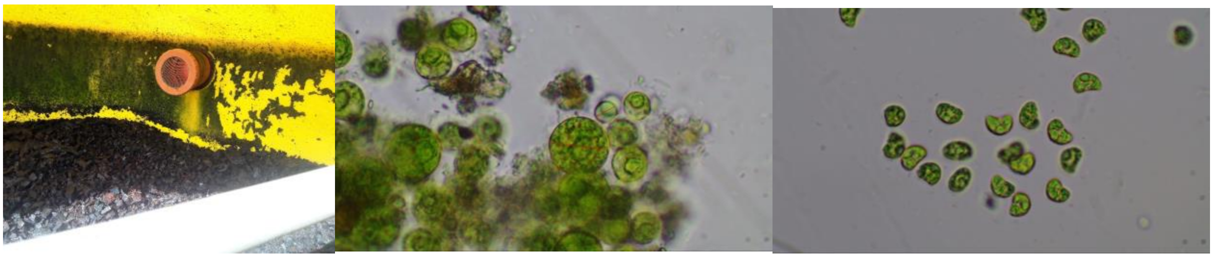


Figure 3-6 The biofilm on the inside walls of the LF(India demo-site) and microscopic images (ob.40x) of harvested microalgae: *Westella sp*. and *Scenedesmus sp*. ()

3.5 Lessons Learned

In the Site Installation and Setup, the experience from the demonstration sites concluded that;

3.5.1 Transportation and Arrival on Site

- In many countries, complex customs and importation procedures can cause extensive delays and lack transparency in the related costs. Local sourcing of components is a potential solution to this problem. However, variations in the quality of locally available products in some countries e.g. Tanzania, were cited as a disadvantage of this approach.
- Planning of the delivery of large equipment onsite is necessary and it is advisable to confirm that the delivery is carried out by a company that are engaged to ensure that that the equipment is safely unloaded at the site in the required location. Where access is limited and special arrangements must be made, these should be well planned in advance.

3.5.2 Enabling Works onsite to Complete Installation

- Advance planning to determine the extent of various expertise required on site to complete enabling works is a key factor in creating efficiencies and avoiding delays.
- Electrical expertise, civil expertise and automation expertise were required to varying degrees at each of the sites and the availability of this expertise proved a challenge at some sites. In addition, coordination between and availability of various trades and expertise can lead to unforeseen delays. Engaging a general contractor with all these skills

is a possible solution to gain efficiencies onsite, however adequate advance planning is a prerequisite.

- The complexity of installation of the MCU as a control device was referenced by a number of demonstration site manager and this issue requires further consideration. The installation of the device as a monitoring system only is a potential solution. Moreover, in countries where low-cost systems are desired, the INNOQUA system may be installed without a MCU.
- Power security in certain countries (India and Tanzania) is a significant issue and despite provision of new infrastructure to provide a dedicated power supply to the INNOQUA system the frequent power outages required a dedicated back up supply. Where requirement for power can be designed out i.e. gravity feeds replace pump feeds this would be advantageous.
- Potential theft, vandalism and trespassing are all elements that require consideration in design in particular at community-based installations where access is not on private property with restricted access. Also, in the case of theft and vandalism, in economically disadvantaged areas.
- Suitable and secure access to the top of the lumbrifilter is required for maintenance and initial setup and in most cases at the demonstration sites this was provided by a proprietary access platform purchased locally which can add considerable expense.
- The initial filling of the lumbrifilter with granular and active layer substrate is a considerable undertaking by hand and consideration should be given to this aspect of the system in the design of the system.
- The insulation arrangement provided at the Irish and Scottish demonstration sites presented some difficulties as the outer aluminium skin was not robust in transportation and tended to separate from the heavier inner plastic tank. In addition, the design did not prevent rainwater ingress to the insulation. Design of a tank with integrated insulation is preferred or underground installation may be adopted.
- Where pipe insulation is necessary due to extreme weather conditions, fitting of insulation to pipes before arrival on site is preferred to make installation more efficient.
- The arrangement onsite of the Lumbrifilter and Daphniafilter systems could be further assessed to take advantage of gravity feeding and reduce the requirement for pumping. This is particularly the case in the global south where power availability is very uncertain.
- The MCU unit required considerable work at the demonstration sites and this could be addressed by the provision of a more complete unit (plug and play) at the outset.

3.5.3 Sourcing Materials and Ancillary Components

- The specification of certain materials and ancillary components should consider the local context and availability to allow flexibility of substitution to avoid unnecessary costs and delays and uncertainty in long supply chains.
- Where local sourcing is not possible i.e. pumps type, flow devices etc consideration should be given to alternatives consistent with local markets or items that can be easily sourced.
- Region specific designs favouring local markets should be considered.

3.5.4 Sourcing Biological Components

- As above, the specification of certain biological materials/components should consider the local context and available to allow flexibility of substitution to avoid unnecessary costs and favour local markets, environments.
- Region specific designs favouring local indigenous species should be considered.
- On a practical note, many earthworms were supplied in an amount of soil or compost – efforts should be made to minimize the amount of this material that is introduced into the lumbrifilter as it can have a negative effect on the effluent quality e.g. in the case of Italy.

4 System Start-up and Commissioning

This stage of the Demonstration Site Implementation includes start-up of the INNOQUA System and its commissioning on site. The following sections review the information provided by each of the sites in answer to a series of comprehensive questions to relating to this element of the works, each section is preceded by the question asked to the demo site managers.
Information below is based on information received from the following demonstration sites numbered 1, 2, 3, 4, 6, 7, 8, 9, 10 and 11 and Prototype Sites 1 and 2 in in Table 1-1.

4.1 Initial System Start-up Lumbrifilter

Briefly Describe the steps followed in the Start-up (first application of wastewater, addition of worms) of the Lumbrifilter include the time period for each step.

Filling of the lumbrifilter with gravels, woodchip etc is a very manual task undertaken generally by the INNOQUA demonstration site managers at each site.
In general, a minimum of 2 weeks of dosing of wastewater to the active layer was completed at the demonstration and prototype sites before addition of earthworms. This period was just 1 week at the Scottish demonstration site.
In the case of the Irish agricultural site, some issues were encountered with the use of a macerating pump causing clogging of the active layer. The macerating pump was replaced by a water pump that was moved to 400mm approximately above the bottom of the tank to avoid pumping of settled solids.
Wood shavings that were used in place of woodchip at the Peruvian demonstration site due to difficulty sourcing woodchip was found to compact very quickly and did not allow for drainage of the wastewater. Coconut husks were added to the sawdust to improve the situation but compacting problems still remained. The distribution system used at the site was a splash plate system and the throttling of the pump to reduce the flow in line with recommendations resulted in clogging of the pump but this was subsequently resolved.
At the French (Nobatek Office) Demonstration site, the perforated pipe distribution system was replaced by a splash plate system after 2 weeks of operation due to clogging in the perforated pipes. The same situation occurred at the Tanzanian site after 10 days of operation
In Tanzania, an inline flow meter device caused restriction of the outflow from the Llumbrifilter and caused flooding of the lumbrifilter and ultimately the original earthworm variety (*Eisenia fetida*) to perish. More importantly, the accumulation of water caused odours that were objectionable to neighbouring community and as a results the installation was relocated. The relocated system was inoculated with locally sourced *Eudrilus eugeniae*.
In India, where coconut husk chips were used in the active layer a coconut fibre was added as membrane to improve retention time, in addition, smaller sized coconut chips were mixed with those initially applied (i.e. 5-15mm) to further improve retention time in the system.

4.2 Initial System Start-up Daphniafilter

Briefly Describe the steps followed in the Start-up of the daphniafilter (first application of wastewater, addition of daphnia) include the time period for each step.

At the NUI Galway Prototype site, live daphnia were sourced from an aquarium supply store and added to the system on the 16th April 2019 (2,000) (based on initial recommendations of 1-3 per litre). The daphniafilter at this stage was receiving treated wastewater from the lumbrifilter system that had been operating since October 2018. The April 2019 daphnia perished soon after addition to the daphniafilter tank and the tank was emptied on the 7th August 2019 and 8,000 daphnia were added on the 13th August 2019 in line with revised recommendation. These daphnia were also sourced from a local aquarium supply store. Visual inspection showed that the daphnia were alive until the beginning of October 2019. From mid October 2019 no daphnia were visible in the system, it was assumed that the drop in water temperature effected the daphnia.

In Scotland, addition of daphnia to the daphniafilter took place 23rd Oct 2019, 3 weeks after earthworms were added to the lumbrifilter at the site. However, after daphnia addition, the water temperature was on average below 5°C (min at 0.1°C) and the daphnia did not survive within the daphniafilter.

The Daphniafilter in Romania was first inoculated after more than one month (04.06.2019) of LF operation with approximately 1000 Daphnias. A second inoculation attempt was performed at the end of August 2019 while a third attempt was initiate on the 17th of October. All inoculations were unsuccessful, the daphnias being impacted by the quality of the influent (high amounts of unauthorised discharges of wall paint residues).

At the Ecuadorian demonstration site, daphnias were introduced one month after earthworms were added to the Lumbrifilter system later but quickly generated issues with smell and with mosquitoes. The daphnia perished and the Daphniafilter unit was converted to a lumbrifilter system.

The experience at the Peruvian Demonstration site was initially that daphnia viability in the daphniafilter was poor and on a number of occasions, each time Daphnias were inoculated they did not survive. The source of the issue was identified as high ammonium discharges into the system, i.e. ammonium at concentrations up to 1200 mg/L, and were affecting both the earthworm population and Daphnias. After a leak at the daphniafilter was repaired in February 2020, the daphnias were re inoculated and have since proved viable improved. In March 2020, the viability was optimal and the system is at is steady state.

In Tanzania, the *daphnia magma* population was replaced by a local cladocera population 1.5 months after the earthworms were added to the connected lumbrifilter, August 2019. The system crashed several times but after stopping the dossing of the daphniafilter for a period of approx. 3 months and further inoculation of cladocera in January 2020, and the system developed a stable cladocera population which has remained viable to February 2020.

At the Indian demonstration site, daphniafilter has not reached a steady state. Daphnia were introduced several times to the system without achieving steady performance. From initially dosing of 30l/hour the dosing was reduced to 10l/h from the lumbrifilter. Efforts to ensure temperature acclimatisation of daphnia prior to inoculation have shown some benefits.

At the UdG Prototype Site good success has been found with the daphniafilter. The following regime was applied: Feed the Daphniafilter reactor with WWTP secondary effluent (2 weeks) in order to allow biofilm growing in the walls. *Daphnia magna* individuals were introduced in the tank, with a concentration of 0.5 D. Magna/L. Previously to Daphnia inoculation, wastewater quality parameters and temperature were measured in order to ensure daphnia growing and survival.

4.3 Initial System Start-up UV System

Briefly describe the steps followed in the Start-up of the UV system (first application of wastewater etc).

The initial start-up of the UV system at the NUI Galway Prototype Site required some system adjustment to ensure that the level sensors triggering the pump to the UV unit and the UV unit was activated only when sufficient minimum volume of effluent to be treated was available downstream of the daphniafilter. Also, that the level sensor allowed for a delayed start of pumping to UV following activation of the UV so that the lamp has sufficient time to heat up (3min). The requirements were completed by the relative size of the UV system to the other units i.e. the UV system at the site is large relative to the other systems. The effectiveness of the UV treatment was impacted by the Daphniafilter function not operating in a consistent manner and then ceasing in October 2019. This situation resulted in Lumbrifilter effluent passing through a stagnant daphniafilter and to the UV system which was resolved by bypassing the daphniafilter unit.

At the Italian demonstration site, the sequencing of the activation of the inlet pump to the UV and the heating of the lamp was the identified as the most important issue for consideration in setup.

At the Indian and Peruvian demonstration sites, the UV systems are in operation following a period of manual operation. A 10 min pre-heating time for the UV system lamp is adopted at the Indian Demonstration Site.

4.4 Initial System Start-up BSP System

The UdG Prototype site first implemented the INNOQUA re designed BSP system following the departure of the partner Heliopur. Some fundamental operational issues were addressed on site and redesign of the system was required before true start up could commence. This process was commenced by the inoculation of the system with river algae biofilm.

The experience of BSP start up at the Peruvian demonstration site was not without challenges, the system was first filled with raw wastewater at the end of September 2019, the same day it was inoculated with pure cultures of *Scenedesmus sp.* (1 L) and *Chlorella*. *sp.* (1 L) – strains from the UCSM collection. From that day on the recirculation pump operated from 6am to 6pm everyday and the biofilm formation took more than a month to establish, requiring a second inoculation in the period.

At the Indian demonstration site, The BSP was inoculated with 20L of lake water collected from 3 different locations: 2 ponds in a local community 10 km away from the demo-site and algae biofilm formed on the inside walls of the lumbrifilter). After one week of operation the BSP had formed a solid algae biofilm on the platform reactors.

Figure 4-1 BSP inoculation and biofilm formed within 1 week - India (left) and BSP inoculation -Peru (right)

4.5 Lessons Learned at System Start-Up

In the Initial Start-Up Phase, the experience from the demonstration sites concluded that;

4.5.1 Lumbrifilter System Start Up

- It is important to limit the introduction to the lumbrifilter of dirt, grit, dust, earth etc that may be attached to gravel, woodchip, coconut chips or with earthworms. These elements should be ideally washed before adding to the Lumbrifiler to make start up more efficient.
- The use of a macerating pump to dose the lumbrifilter can lead to some difficulties with a sludge solids layer forming on the top of the lumbrifilter and making it difficult for water to penetrate and reach the active layer. The use of a water pump placed at sufficient height above the settled sludge layer in a settlement tank is a viable option. The presence of rags in the settlement tank causing blockage to a macerating pump can be resolved by similar improved positioning of the pump in the settlement tank.
- The use of a splash plate dosing system in place of a perforated pipe distribution system reduced the occurrence of clogging and required maintenance.
- The availability of suitable active layer substrate material should be considered in region specific designs. Recommended specification for such woodchip alternative materials should be provided.
- Consideration should be given to the specification of simplified low cost flow monitoring devices that do not inhibit flow and can handle the presence of some solid material.

4.5.2 Daphniafilter System Start Up

- The availability of suitable daphnia species or similar planktonic crustaceans should be considered in region specific designs and appropriate specification for alternatives to *Daphnia Magna* provided.

- The sensitivity of the daphnia to environmental conditions in general and temperature change in particular, temperature drops, should be considered in region specific designs and or commercial offering. In particular for water stressed areas the viable temperatures for daphnia are likely to coincide with prolonged dry periods.
- In the case of the Daphniafilter it is essential to control wastewater quality parameters and water temperature before the inoculation of the daphnia to ensure their best chance of survival.

4.5.3 UV System Start Up

- Clear direction is necessary to ensure efficient and correct integration of the UV system and daphniafilter or lumbrifilter system to account for adequate preheating of the UV lamp.
- Appropriate sizing of the UV system to correspond with the capacity of the upstream system units is required.

4.5.4. BSP System start-up

- The biofilm layer on the platform and steady state performance of the BSP system have been reached faster when fed with LF effluent (India) instead of raw wastewater (Peru), with full feeding and operation according to design since inoculation (India) compared to recirculation mainly with limited feeding of the system with raw wastewater (Peru).

5 System Operation

This stage of the Demonstration Site Implementation considers the operation of the INNOQUA System on site. The following sections review the information provided by each of the sites in answer to a series of comprehensive questions to relating to this element of the works, each section is preceded by the question asked to the demo site managers.
Information below is based on information received from the following demonstration sites numbered 1, 2, 3, 4, 6, 7, 8, 9, 10 and 11 and Prototype Sites 1 and 2 in in Table 1-1.

5.1 Reaching Steady-State

Briefly describe how you concluded that the lumbrifilter system had reached steady state operation

In general, at all of the demonstration and prototype sites, the lumbrifilters installed at the demonstration and prototype sites were considered operating at steady state when treatment performances where stable across 4 consecutive weeks following addition of earthworms to the system and this process took approximately 60 days/2 months.
In particular, at the French Nobatek Demonstration the following sequence was recorded, a period of 2 months elapsed between introduction of the earthworms and achieving steady state operation. The perforated pipe distribution system was replaced by a splash plate system during this period following clogging of the perforations.
In Italy, 60 days were recorded between earthworm introduction and achieving steady state operation. In Scotland, a period of just one week elapsed between earthworm introduction and steady state.
In Romania, steady state performance was achieved within 1 month, however after 3 months the performances have been impacted temporary by unauthorized discharges of wall paint and construction material residues within the influent.
In Ecuador and Peru, certain operational issues i.e. developing an appropriate pumping solution and active layer compaction (Peru), caused delays achieving a satisfactory steady state is achieved.

Briefly describe how you concluded that the daphniafilter system had reached steady state operation

Limited success was achieved with maintaining daphnia population to reach steady state. Of the 9 demonstration and 2 prototype sites, a population was maintained in 3 of the sites. It is likely that a combination of factors contributed to this result and these are addressed in Project Deliverable 5.2.

Briefly describe how you concluded that the BSP system had reached steady state operation

In the case of the BSP following final configuration changes at the prototype site in Girona, steady state operation was reached after 2 weeks of continual operation when there was almost constant removal of organic matter and nutrients. However, as is the case for the daphniafilter, the operation of nature-based biological systems can vary a lot over a short period of time. It was observed that the optimum performance can last one or two weeks, before the system starts to experience loss of performance and then to recover it back. This operation is normal and expected for systems that follow a natural cycle.

5.2 Operational Issues

How long did the Lumbrifilter system initially operate at steady state without encountering any operational issues? Describe the first (if any) operational issue encountered.

At the Irish agricultural Demonstration site some issues were encountered with the pump clogging shortly after, i.e. a number of weeks, after reaching steady state. The relocation of the pump to above the expected settled sludge level resolved this issue, together with sludge removal from the settlement tank every 2 month. This situation was also encountered at the NUI Galway Prototype Site and a similar resolution found.

Clogging of the system by increased sludge and heavy solids accumulation at the top of the Lumbrifilter was experienced at a number of sites at periods from 1-2 weeks after steady state to 2-3 months after steady state. The repositioning of the influent pump above the settled sludge level and a desludging and agitation of the top active layer as maintenance operations were the solutions.

The French Nobatek demonstration site continued operation for a period of 3 months with no settlement facility and dosing via a splash plate.

In Italy, the lumbrifilter at the demonstration site has continued to operate without any operational issues to the time of this report. One note is that earthworms are being found in the Lumbrifilter effluent, this was also the case at the Indian demonstration site. For the Romanian demo-site, the Lumbrifilter was impacted by the occasional unauthorised discharges of wall paint residues related to the general renovation (July-October 2019) aiming to change the destination of the building from touristic to office building.

At the Peruvian demonstration site, high levels of ammonia in the Lumbrifilter influent appeared to compromise the earthworm population. The high levels of ammonium were observed in mid-December. This was attributed to the effluent from one of the laboratories on campus that performs soil quality tests and did not have an adequate disposition of reagents; after this date, the laboratory began to separate its reagents and the problem was solved.

How long did the Daphniafilter system initially operate at steady state without encountering any operational issues? Describe the first (if any) operational issue encountered.

At the UdG Prototype site in Spain, the system remained good performance for a period of 2 months after initial steady state was reached. The first operational issue was the depleting conditions for daphnia population when several stressors occurred simultaneously (high COD and NH_4^+ load, together with high temperatures). In addition, over time a growth of Lemna occurred on top of the Daphniafilter this should be removed or will obscure light penetration.

The daphniafilter operation in Peru and Tanzania at the time of writing is continuing without operational issues. With the exception of an overpopulation of tadpoles during February in the Tanzania demosite that fed on cladocera causing their depletion, thus affecting the performance of the system.

How long did the UV system initially operate at steady state without encountering any operational issues? Describe the first (if any) operational issue encountered.

The main operational issues with the UV relate to reduced performance unless lamp is cleaned frequently. At the UdG prototype site this was required after 2 weeks of operation and at the NUI Galway prototype site. Recommendation from technology provider BUV that UV lamp is cleaned weekly if problem is occurring.

At the Peruvian demonstration site, damage to a sensor was reported and this was replaced 3 months after start up. The first time the UV lamp was installed, a SYSTEM ERROR was detected on the main screen and light intensity was not detected, it was determined that this happened because of a damage to the sensor, in January the sensor was replaced and the light intensity began to be detected, currently no light intensity is detected but it seems to be due to the fact that the lamp has not been cleaned; in February the relay module for activating the lamp burnt out and had to be replaced.

How long did the BSP system initially operate at steady state without encountering any operational issues? Describe the first (if any) operational issue encountered.

Some issues were encountered at the Peruvian demonstration site with the feed pump and these occurred within the first month of operation. The incidence of Mayfly and Chironomidae larvae in the biofilm was also observed at this site since the BSP platforms reproduces a natural environment rich in microalgae. At the UdG Prototype site, after one month, the biofilm started to lose its grip on the surface of the BSP, therefore it gets loose and can be washed out from the reactor.
There is an observed continuous growth of biofilm at the BSP in the Indian demonstration site and this requires some clearing/removal at a time to be confirmed.

5.3 Stakeholder Engagement

Describe any stakeholder engagement that was undertaken during the regular system operation

The main stakeholder consultation during the operation phase was with external laboratories undertaking the analysis on behalf of the demonstration sites.
In the case of the Scottish demonstration site, extensive stakeholder consultation had taken place at planning stage with the local community and maintenance and operational monitoring plans were well established at this time. Some consultation was required at the operation stage between Scottish Water (SW) Operations team, the contractor and SW Horizons (SW Horizons is an independent company related to SW responsible for maintaining the INNOQUA system during weekly visits).
The proximity to the site and availability of the system routine maintenance and operation team proved to be an issue for some sites in addressing potential issues quickly.
In the case of the Indian demonstration site, neighbours complained about the smell of the INNOQUA system and constant exchange and engagement with this stakeholder group was require to de-escalate the situation.

5.4 Lessons Learned

In the System Operation Phase, the experience from the demonstration sites concluded that;

5.4.1 Reaching Steady State in the INNOQUA Systems

- The period of dosing of the Lumbrifilter system with wastewater prior to the addition of earthworms could potentially be reduced to less than two weeks, this is to be investigated further potentially through laboratory experimentation. The experience at the Scottish demonstration site where a period of just 1 week of dosing was maintained before addition of the earthworms indicates that this reduction in initial dosing period in the absence of earthworms did not have a negative consequence.
- Performance monitoring is necessary from the start-up phase to accurately determine the system performance.
- The performance of a nature-based systems that follow a natural cycle of the biological organisms will result in operational variations. One lesson may be to highlight some operating conditions which can allow these NBS to keep the steady state operation as long as the system allows it.

5.4.2 Operational Issues

- The issue of effluent flow from the system being representative of influent flow can lead to some inaccuracies if clogging of the system occurs in particular. Consideration could be given to the inclusion of simple flow measurement devise at inflow and outflow. Inline flow meters suitable for foul water can be expensive and require a large flow and the experience at the Irish prototype site on installing an inline water flowmeter on inlet and at the Tanzanian demonstration site at outlet was to cause considerable flow blockage and subsequent overflow.
- Issues of pump clogging and related failures were common experiences at the sites, in particular in relation to the lumbrifilter influent.
- Also when heavy solids pumped to the top of the lumbrifilter and compacted this layer became a barrier for additional water to percolate through the system causing flooding at the top of the lumbrifilter and odours. At sites, the situation was improved by 1) increasing the height of the pump in the retention tank upstream of the lumbrifilter inlet to above the expected sludge level 2) carrying out frequent desludging of the retention tank in the case of heavy solids influent i.e. at the agricultural site in Ireland. 3) routine agitation of the top surface of the lumbrifilter to prevent compaction of sludge material 4) use of vents/odour filters to prevent build up of foul odours. Agitation of the top surface of a large lumbrifilter tank e.g. that in Tanzania which is 3.5m^2 surface area is a physically demanding task and consideration can be given to suitability of a series of smaller tanks for more locations that do not have a suitable maintenance resource.
- The use of a macerating pump at the inlet to the lumbrifilter at the NUI Galway Prototype site and at the agricultural demonstration site led to increased solids and build up. In addition, the macerating pumps trialed had a tendency to become clogged. It was concluded that the operation of the macerating pump at the relatively low flows/short flow

periods required by the lumbrifilter was not compatible with the normal operating range of the macerating pumps. Difficulties were also experienced at the Scottish demonstration site in operating the macerating pump with problems occurring weekly early in the operation stage. The macerating pumps at the Irish sites were replaced by suitable foul water pumps.

- In the case of the Ecuadorian and French Nobatek demonstration sites, the surface area available at the tank was found to be insufficient for the load experienced at the site. The sizing of the units should be carefully reviewed with reference to the expected nutrient load.
- The presence of earthworms in the lumbrifilter effluent at some demonstration sites requires further investigation and perhaps inclusion in a troubleshooting guide
- The negative effect of exceptionally high ammonia levels in the lumbrifilter and daphniafilter requires some preventative measures.
- The control of the biofilm at the BSP in the case of excessive growth or loss needs further definition perhaps in a troubleshooting guide.
- Use of a splash plate distribution system was found to be the most maintenance free solution to providing an appropriate distribution solution for the lumbrifilter, with the majority of demonstration sites opting for this solution.
- Reliability of one laboratory in particular engaged to carry our performance monitoring proved to be a significant issue for one demonstration site.
- Power outages in Tanzania effected the operation of the system requiring a back-up power supply to be installed, this is unlikely to be a viable solution in a commercial environment.

5.4.3 Stakeholder Engagement

- The importance of comprehensive stakeholder engagement is confirmed by the contrasting experiences in the Scottish and Indian and Tanzanian demonstration sites.

6 System Maintenance

This stage of the Demonstration Site Implementation considers specifically the maintenance of the INNOQUA System on site. The following sections review the information provided by each of the sites in answer to a series of comprehensive questions to relating to this element of the works, each section is preceded by the question asked to the demo site managers.
Information below is based on information received from the following demonstration sites numbered 1, 2, 3, 4, 6, 7, 8, 9, 10 and 11 and Prototype Sites 1 and 2 in in Table 1-1.

6.1 Routine Maintenance

Briefly Describe the routine maintenance carried out on the Lumbrifilter system and indicate the frequency of this maintenance

At the Scottish, Irish, Tanzanian and Indian demonstration sites agitation of the top surface of the lumbrifilter was carried out on a weekly or fortnightly basis, the other sites did not follow this regime. The compaction of the sawdust in the active layer and frequent attacks on cables and equipment by animals at the Peruvian demonstration site necessitated increased interventions and maintenance monitoring on a daily basis for a period.
At the Irish prototype and demonstration site addition of woodchip (100-200mm depth approx.) was required on a 2 monthly basis to maintain the required 1m woodchip height. At all sites the height of the active layer was checked routinely and woodchip or other material relevant to the site was added to maintain the active layer at 1m depth. The Italian demo site and UdG Prototype site recorded that this was necessary only after 3, 5 months operation, respectively.
Visual inspections were carried out frequently at sites on a weekly or biweekly basis to ensure operation of pumps and presence of a worm population in the lumbrifilter.
The Italian demonstration site reported a build-up of sludge at the outlet of the lumbrifilter that required removal after 67 days of operation. A grease trap in advance of the lumbrifilter at this site also required cleaning at intervals of 3 to 6 months.
No routine maintenance of the Romanian Lumbrifilter, only occasional visual check of the earthworms' viability.

Briefly Describe the routine maintenance carried out on the Daphniafilter system and indicate the frequency of this maintenance

At the Tanzanian demonstration site, once every two weeks mosquito larvae of tadpoles were removed from the Daphniafilter and a mosquito net was placed on the top of the filter to avoid mosquito laying eggs.
From time to time bit with no regular frequency, floating solids and grasses were removed tank.
At least once a week the cladocera population was checked in a visual inspection of a 100ml sample to confirm the presence in the filter.

Algae on the top surface of the Daphniafilter was removed on a weekly basis to avoid total coverage of surface and potentially blockage of sunlight entering for daphnia. Biomass and sludge at the bottom of the Daphniafilter were not removed from the Daphniafilter during the trial.

At the UdG Prototype site, the routine maintenance of the Daphniafilter consisted of checking the daphnia population every 2 weeks and checking the production of algae at the water surface. This was removed every 2 weeks. Efforts were made to avoid proliferation of mosquitos by ensuring a regular relatively constant influent flow so as to avoid stagnant water for periods.

In Romania, the daphniafilter was emptied, cleaned and filled with fresh well water before inoculation 2 and 3.

Briefly Describe the routine maintenance carried out on the UV system and indicate the frequency of this maintenance

Routine maintenance of the UV system generally comprised weekly cleaning of the system lamp.

Briefly Describe the routine maintenance carried out on the BSP system and indicate the frequency of this maintenance

The BSP system at the Peruvian demonstration site suffered issues related to the BSP influent pump operational control. This led to a noted presence of insect larvae in the biofilm due to periods of inactivity.

Visual inspection is generally the only form of routine maintenance carried out at the BSP in the Indian demonstration site and the UdG Prototype Site.

Briefly Describe the routine maintenance carried out on the MCU system and indicate the frequency of this maintenance

The monitoring probes required cleaning frequently – this varied between sites from weekly to every 3 months.

6.2 Site Specific Maintenance

Briefly describe any site maintenance required to be carried out on the system/set-up that was specifically related to site/local conditions, indicate the frequency of this maintenance

Due to the high solids content of the wastewater at the agricultural site in Ireland, relatively frequent (every 2 months) desludging of the settlement tank was required.

At the Scottish demonstration site, the impact of extremely cold (sub-zero) conditions required inspection of influent to identify freezing conditions.

The location of the Peruvian demonstration site near an agricultural area increased the presence of vermin, small animals and insects, these caused some damage to the cables and pipework. Heavy rains experienced at the site caused increase in the water table level and resulted in floatation of some buried tanks.

Power outages in Tanzania effected the operation of the MCU system requiring additional maintenance.

Protection of the system from very heavy rains experience in Peru was identified as generating maintenance requirements. The lid provided with the system did not protect against the ingress of rain.

6.3 Comparative Review Summary

6.4 Lessons Learned

In the System Maintenance Phase, the experience from the demonstration sites concluded that;

6.4.1 Routine Maintenance

- Frequent (weekly, fortnightly) agitation of the top surface of the lumbrifilter is required to ensure good percolation of the wastewater. Depending on the tank size, this can be a physically demanding task so consideration to be given to who will provide maintenance activity in the recommendation of suitable system configurations.
- Addition of active layer material to maintain a minimum 1m active layer depth is required at intervals but varies from site to site. Clear indication or marking in the tank of the required level is required to assist this maintenance activity.
- Weekly or biweekly removal of algae from the top surface of the Daphniafilter was the main routine maintenance activity in the warm weather demonstration sites. In addition, removal every two weeks of mosquito larvae and tadpoles. A mosquito net resolved the mosquito and tadpole issue.
- The monitoring probes attached to the MCU required regular cleaning, this varied between sites from weekly to every 3 months and additional guidance is required on this.
- A minimum routine maintenance programme should be provided for all of the system elements.

6.4.2 Site Specific Maintenance

- In the case of wastewater with a high solids content, it is likely that relatively frequent desludging of any retention tank upstream of the lumbrifilter will be required, this should be identified in the maintenance protocols.
- The issue of temperature and climate extremes impacting the system operation from extreme rainfall to freezing conditions or very high temperatures should be addressed in operation and maintenance protocols for the system and include recommendations for mitigating interventions.
- The assessment of site suitability in particular for buried tanks should include an assessment of likely fluctuations in water table.
- The proximity to the site and availability of the system routine maintenance and operation team proved to be an issue for some sites in addressing potential issues quickly. This confirms the importance of the remote monitoring and control systems for the sites

7 Applying the Lessons

7.1 Introduction

Many and varied valuable lessons have been identified from the experience of the INNOQUA Demonstration Site Managers and INNOQUA Project Team through the process the demonstration site implementation from Planning and Advance Works to System Maintenance as described in the preceding chapters and referenced in Figure 7-1.

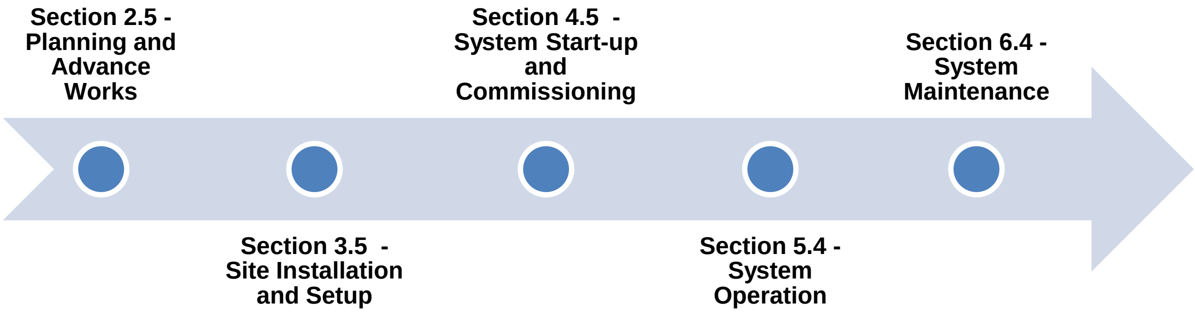
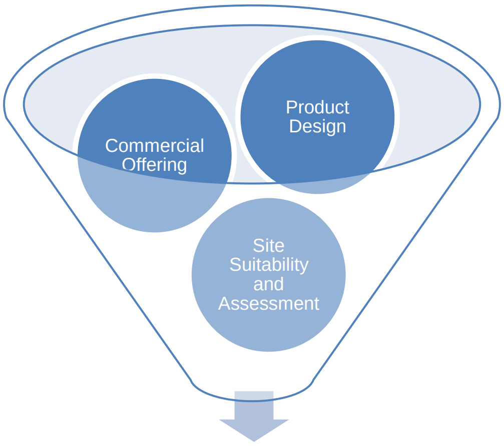


Figure 7-1 Lessons from Site Implementation Process Summary Guide

The future development of the INNOQUA System will in many ways be dictated by the commercialization path followed and this is addressed in ***Project Deliverable D6.4 Exploitation, Business Plans and Commercialization.*** However irrespective of the identified path, a number of elements as indicated by will require consideration in the further development of the INNOQUA offering and these provide a clear opportunity to implement the lessons learned in the preceding chapters to further improve the INNOQUA System in readiness for the commercial market.



Implementation Protocols
Operational Protocols
Maintenance Protocols

Figure 7-2 Further Development of the INNOQUA System

Sections 7.2 – 7.6 following, map each of the Lessons from the 5 demonstration Site Implementation Phases (ref. Figure 7-1) to the most relevant aspect of the future development of the INNOQUA System.

7.1.1 Commercial Offering

The development of a commercial offering that will be relevant to the INNOQUA system is addressed in *D6.4 Exploitation, Business Plans and Commercialization*. In detail, an update of the aforementioned deliverable is foreseen before the end of the project (M51) where a Commercialization plan will be arranged for targeted markets, the commercialization plan will be accompanied by an agreement among the interested partners and this agreement will pave the way for the INNOQUA ALLIANCE (IA). The IA agreement will be the basis point of the commercialization of the INNOQUA system that will be released as a Product as a Service (PaaS). The product will be marketed as a combination of one or more modules composing the integrated wastewater system according to the needs of each application and local market regulations. Main business actors targeted will be local contractor operating the water sector.

7.1.2 Product Design

The demonstration sites were the first opportunity for the INNOQUA system to be trialled in real world operational conditions and as expected some revisions to the current system designs are recommended. These are addressed further in ***D6.2 Best Practice Guidelines for Design, Installation and Operation***.

7.1.3 Site Suitability and Assessment

An assessment of the suitability of any site or location for application of a particular wastewater treatment system is a key aspect for consideration and can inform later layout and setup decisions. Consideration of available power, wastewater characteristics, climate variations. These are addressed further in ***D6.2 Best Practice Guidelines for Design, Installation and Operation***.

7.1.4 Implementation, Operation and Maintenance Protocols

Clear and practical guidelines for the Installation, Operation and Maintenance of any new system is a prerequisite for its future success. The wide scale deployment of the INNOQUA System in real world conditions while still in development provides a unique wealth of practical knowledge and lessons learned to contribute to ***D6.2 Best Practice Guidelines for Design, Installation and Operation***.

7.2 Applying the Lessons - Planning and Advance Works

Table 7-1 below maps the Lessons from **Planning and Advanced Works** to the most relevant aspect of the future development of the INNOQUA System.

Table 7-1 Mapping Lessons from Planning and Advanced Works

Lessons from Planning and Advanced Works	Commercial Offering D6.4	Product Design D6.2	Site Suitability D6.2	I, O, M Protocols D6.2
Section 2.5.1 Identifying the Demonstration Site				
Accessibility of site to routine maintenance persons			✓	
Low occupancy of site – less than expected influent			✓	✓
Adaptation of tank shape to suit restricted site is possible			✓	
Adaptation of tank configuration at a restricted site is possible	✓	✓	✓	
Commercially viable system of locally (EcD) sourced materials	✓	✓		
Social acceptance of system in low income communities in global south is challenged by shortage of most basic needs	✓		✓	
Higher income locations in global south will prioritise sanitation			✓	
Section 2.5.2 Planning and Location				
Identify early need and likely duration to secure permits and permissions as delays will impact installation schedule			✓	
Section 2.5.3 Pre installation Site Works				
Installation of the INNOQUA System as part of a new build limits work on site pre installation	✓		✓	
When engaging external contractors, a minimum of 3 quotations should be sought to ensure value for money	✓		✓	✓
Suitably qualified personnel should confirm the site assessment to identify early extent of works required			✓	
Section 2.5.4 Stakeholder Engagement				
Early stakeholder identification and engagement is key aspect to success particularly in a community setting.	✓		✓	

Pre installation workshops are recommended in low income areas in Global South to inform on benefits of sanitation	✓		✓	✓

7.3 Site Installation and Initial Setup

Table 7-2 below maps the Lessons from **Site Installation and Initial Setup** to the most relevant aspect of the future development of the INNOQUA System.

Table 7-2 Mapping Lessons from Site Installation and Initial Setup

Site Installation and Initial Setup	**Commercial Offering D6.4**	**Product Design D6.2**	**Site Suitability D6.2**	**I, O, M Protocols D6.2**
Section 3.5.1 Transportation and Arrival on Site				
Customs and importation procedures can cause delays and costs – can be avoided by local sourcing of product/materials	✓			
Variations in quality of locally sourced materials may affect performance – minimum quality required to be defined		✓		✓
Careful planning of the delivery of large equipment (i.e. tanks) onsite is required for safe delivery and unloading in place.			✓	✓
Adaptation of tank configuration at a restricted site is possible	✓	✓	✓	
Commercially viable system of locally (EcD) sourced materials	✓	✓		
Social acceptance of system in low income communities in global south is challenged by shortage of most basic needs	✓		✓	
Higher income locations in global south will prioritise sanitation			✓	
Section 3.5.2 Enabling Works onsite to Complete Installation				
Planning required to determine the various expertise needed (mech, elect etc) to avoiding delays and create efficiencies.		✓		✓
Availability and coordination of expertise (mech, elect, etc) can be avoided by engaging a general contractor for install.	✓			✓
Installation of the the MCU as a control device requires further consideration.	✓	✓		✓
The installation of the device as a monitoring system only is a potential solution	✓	✓		✓
Lack of power security for pump operation is an issue in some regions – gravity fed solution would avoid dependency		✓	✓	✓
Risk of theft, vandalism and trespassing require consideration esp. in Community installations where access is not restricted			✓	✓
Suitable and secure access to the top of the lumbrifilter (when above ground) is required this could be integrated to design		✓	✓	✓

Filling of the lumbrifilter with granular/active layer material can be a very physical undertaking requiring further consideration	✓	✓		✓

Table 7-2 (continued) Mapping Lessons from Site Installation and Initial Setup

Site Installation and Initial Setup	Commercial Offering D6.4	Product Design D6.2	Site Suitability D6.2	I, O, M Protocols D6.2
The insulated lumbrifilter tank outer aluminium shell was not robust in transportation – this requires design consideration		✓		✓
Insulated lumbrifilter tank outer shell not water tight at pipe opes/lid and lid not robust - requires design consideration		✓		✓
Design of a tank with integrated insulation is preferable		✓	✓	
Pipe insulation where required due to extreme weather should be fitted before arrival on site as more efficient.				✓
Avoiding the need for pumps would provide considerable advantages particularly where power supply is uncertain		✓	✓	
Section 3.5.3 Sourcing Materials and Ancillary Components				
The specification of materials and ancillary components should allow flexibility of substitution to local supply	✓	✓		✓
Region specific equipment design and specifications favouring local markets should be provided		✓	✓	✓
Section 3.5.4 Sourcing Biological Components				
Specification of biological materials (earthworm, daphnia etc) should consider the local context/allow flexibility of substitution		✓	✓	✓
Region specific designs favouring local indigenous species should be considered.		✓	✓	✓
Minimize the amount of soil/compost with which earthworms are supplied being introduced into the lumbrifilter				✓

7.4 System Start-up and Commissioning

Table 7-3 below maps the Lessons from **System Start-up and Commissioning** to the most relevant aspect of the future development of the INNOQUA System.

Table 7-3 Mapping Lessons from System Start-up and Commissioning

System Start-up and Commissioning	Commercial Offering D6.4	Product Design D6.2	Site Suitability D6.2	I, O, M Protocols D6.2
Section 4.5.1 Lumbrifilter System Start Up				
Introduction of dirt, grit, dust, earth etc attached to gravel, woodchip, coconut chips or with earthworms should be limited				✓
Gravel, woodchip, coconut chips ideally should be washed prior to addition to the lumbrifilter				✓
Careful consideration should be made in use of a macerating pump to dose the lumbrifilter as can lead to impermeable sludge solids layer forming on the top of the lumbrifilter		✓		✓
The presence of rags in the settlement tank causing blockage to macerating pumps can be improved by positioning of pump in the settlement tank above settled sludge layer.		✓		✓
The use of a water pump placed at sufficient height above the settled sludge layer in a settlement tank is a viable alternative to macerating pump		✓		✓
Compatibility of flow required for dosing and macerating pump operating range can be challenge		✓		✓
The use of a splash plate dosing system in place of a perforated pipe distribution system reduced the occurrence of clogging and required maintenance in all cases		✓		✓
Consideration should be given to the specification of simplified low cost flow monitoring devices that do not inhibit flow and can handle the presence of some solid material		✓		✓
Section 4.5.2 Daphniafilter System Start Up				
The availability of suitable daphnia species or similar planktonic crustaceans should be considered in region specific designs and appropriate specification for alternatives provided		✓		✓
The sensitivity of the daphnia to temperature change in particular, temperature drops, should be considered in region specific designs and or commercial offering	✓	✓	✓	✓
For water stressed areas the viable temperatures for daphnia are likely to coincide with prolonged dry periods this can be a positive in region specific designs	✓	✓	✓	✓
It is essential to control wastewater quality parameters and water temperature before the inoculation of the daphnia to ensure their best chance of survival.		✓		✓

Table 7-3 (continued) Mapping Lessons from System Start-up and Commissioning

System Start-up and Commissioning	Commercial Offering D6.4	Product Design D6.2	Site Suitability D6.2	I, O, M Protocols D6.2
Section 4.5.3 UV System Start Up				
Clear direction is necessary to ensure efficient and correct integration of the UV system and daphniafilter or lumbrifilter system to account for adequate preheating of the UV lamp				✓
Appropriate sizing of the UV system to correspond with the capacity of the upstream system units is required		✓		✓

7.5 System Operation

Table 7-4 below maps the Lessons from **System Operation** to the most relevant aspect of the future development of the INNOQUA System.

Table 7-4 Mapping Lessons from System Operation

System Operation	Commercial Offering D6.4	Product Design D6.2	Site Suitability D6.2	I, O, M Protocols D6.2
Section 5.4.1 Reaching Steady State in the INNOQUA Systems				
The period of dosing of the lumbrifilter system with wastewater prior to the addition of earthworms could be reduced		✓		✓
Performance monitoring is necessary from the start-up phase to accurately determine the system performance				✓
Nature-based systems that follow a natural cycle of the biological organisms will result in operational variations				✓
Recommended operating conditions should be those that allow NBS to keep steady state operation as long as possible		✓		✓
Section 5.4.2 Operational Issues				
The issue of effluent flow from the system being representative of influent flow can lead to some inaccuracies if clogging of the system occurs in particular		✓		✓

Table 7-4 (continued) Mapping Lessons from System Operation

System Operation	Commercial Offering D6.4	Product Design D6.2	Site Suitability D6.2	I, O, M Protocols D6.2
Consideration should be given to the specification of simplified low cost flow monitoring devices that do not inhibit flow and can handle the presence of some solid material (as per Table 7.3)		✓		✓
Issues of pump clogging and related failures were common experiences at the sites, in particular in relation to the lumbrifilter influent.		✓		✓
Heavy solids pumped to the top of the lumbrifilter can compact and form a barrier for additional water to percolate through the system - may result in flooding and odours		✓		✓
Solutions to compact sludge solids layer were identified: 1) Increased the height of pump in the retention tank upstream of the lumbrifilter inlet		✓		✓
Solutions to compact sludge solids layer were identified: 2) desludging (every 2 months) of the retention tank in the case of heavy solids influent i.e. at the agricultural site		✓		✓
Solutions to compact sludge solids layer were identified: 3) Regular (weekly or biweekly) agitation/raking of the top surface of the lumbrifilter		✓		✓
Solutions to compact sludge solids layer were identified: 4) use of vents/odour filters to prevent build-up of foul odours		✓		✓
Large dia lumbrifilter tanks can be difficult/physically demanding to carry out manual agitation		✓		✓
A series of smaller lumbrifilter tanks may be easier to maintain than one large one (ref above)	✓	✓	✓	✓
Operation of macerating pump at inlet to lumbrifilter at the relatively low flows/short flow periods required was not compatible with expected operating range of this pump type.		✓		✓
Suitable foul water pumps above the expected settled sludge level in retention tank upstream of lumbrifilter is successful		✓		✓
The sizing of the lumbrifilter units should be carefully considered with reference to the expected nutrient load.		✓	✓	
Exceptionally high ammonia levels in the lumbrifilter and Daphniafilter have very negative consequences - requires some preventative measures		✓	✓	✓

Table 7-4 (continued) Mapping Lessons from System Operation

System Operation	Commercial Offering D6.4	Product Design D6.2	Site Suitability D6.2	I, O, M Protocols D6.2
Consideration should be given to the specification of simplified low cost flow monitoring devices that do not inhibit flow and can handle the presence of some solid material (as per Table 7.3)		✓		✓
The presence of earthworms in the lumbrifilter effluent at two of demonstration sites requires further investigation – consider for inclusion in a troubleshooting guide		✓		✓
The control of the biofilm at the BSP in the case of excessive growth or loss needs further definition – consider for inclusion in a troubleshooting guide		✓		✓
A splash plate distribution system is a maintenance free solution to providing distribution to the lumbrifilter		✓		✓
Reliability of laboratories engaged to carry our performance monitoring should be carefully considered	✓			✓
Frequent power outages negatively effected the operation of the system in power insecure locations – a dedicated backup power supply is likely to be commercially unviable	✓	✓	✓	✓
Principally gravity fed systems without power dependency could be more viable solution for power insecure locations	✓	✓	✓	✓
Section 5.4.3 Stakeholder Engagement				
The importance of comprehensive and early stakeholder engagement is confirmed by the contrasting experiences in the demonstration sites that engaged and those that did not			✓	✓
Remote monitoring systems are important for sites without local maintenance capabilities	✓	✓	✓	✓

7.6 System Maintenance

Table 7-5 below maps the Lessons from **System Maintenance** to the most relevant aspect of the future development of the INNOQUA System.

Table 7-5 Mapping Lessons from System Maintenance

System Maintenance	Commercial Offering D6.4	Product Design D6.2	Site Suitability D6.2	I, O, M Protocols D6.2
Section 6.4.1 Routine Maintenance				
Frequent (weekly, fortnightly) agitation of the top surface of the lumbrifilter is required to ensure good percolation of the wastewater				✓
Depending on the tank size, agitation of the top surface of the lumbrifilter can be a physically demanding task. Consideration to be given to who will provide maintenance activity in the recommendation of suitable system configurations	✓			✓
Additional active layer material to maintain a min 1m active layer depth is required at intervals varying from site to site (every 2 months approx.)			✓	✓
Clear indication or marking in the tank of the min 1m active layer is required to assist maintenance level		✓		✓
Weekly or biweekly removal of algae from the top surface of the daphniafilter was the main routine maintenance activity in hot climates		✓		✓
Addition of a mosquito net at the daphniafilter is required in hot climates to prevent mosquito larvae and tadpoles		✓	✓	✓
The monitoring probes attached to the MCU require regular cleaning, this varied between sites from weekly to every 3 months and additional guidance is required on this				✓
To account for variations, details of a minimum routine maintenance programme is required for all of the system elements				✓
Section 6.4.2 Site Specific Maintenance				
In the case of wastewater with a high solids content, it is likely that relatively frequent desludging of any retention tank upstream of the lumbrifilter will be required				✓
The issue of temperature and climate extremes on system operation from extreme rainfall to freezing conditions or very high temperatures should be addressed in operation and maintenance protocols for the system and include recommendations for mitigating interventions		✓		✓
Assessment of site suitability in particular for buried tanks to include assessment of likely fluctuations in water table.		✓	✓	✓

Table 7-5 (cont'd) Mapping Lessons from System Maintenance

System Maintenance	Commercial Offering D6.4	Product Design D6.2	Site Suitability D6.2	I, O, M Protocols D6.2
The proximity to the site and availability of the system routine maintenance and operation team proved to be an issue for some sites in addressing potential issues quickly - importance of the remote monitoring systems	✓	✓	✓	✓

8 Local Manufacturing Organisation and Material Sourcing for Overseas Markets

8.1 Introduction

The INNOQUA project was organized so that, for experimental and demonstration purpose, the INNOQUA systems was prototyped in Europe and sent to each pilot country. This organisation fully made sense for the project time frame. It was the easiest way to guarantee the conform similarity between the different tanks used for the Lumbrifilter and the Daphniafilter. Moreover, we are ensuring that the tank used where conform to European certification and especially the EN12566-3.
The demonstration phase shows in which extend this organisation was not accurate for further exploitation in oversea market, in these cases, material importation and oversea transportation generate a considerable set of barriers:

Sustainability: material transportation over long distance is often considered as strong environmental issue related to climate change impact generated by oversea boats. It is, in the case of INNOQUA, reinforced by the fact that tanks are empty and, despite their low weight, occupy an important space.

Cost: transport cost may be a considerable barrier for a system destined for developing countries markets. Cost associated to the manufacturing process realized in Europe, under European quality standards, may also hinder the capacity of the system to be exploited in poorer countries. Eventually, considerable custom taxes applied for the importation of oversea products in many developing countries (e.g. Ecuador) should seriously difficult the selling of a product that should reach a very low cost in countries where the sanitation market is strongly ruled by economical statements.

Organization of the local exploitation: oversea transportation time and treatment of the importation process in the local custom administration are also important difficulties to face in the commercialisation of a fully imported system in the targeted developing countries. Such barriers were concretely experimented for the demonstration sites of the project and the resulting experience is detailed further on.

Hence in order to upscale the industrialisation process for those markets (i.e. India, Tanzania and Ecuador) under real industrial exploitation conditions, it was necessary to develop, once the system was validated, an alternative organisation for the manufacture of the system and for the furniture of materials and elements: manufacture not being centralised in Europe and materials ideally locally produced and transformed.
Such work was conducted for the Indian, Tanzanian and Ecuadorian pilots, looking for a local fabrication perspective in line with sustainability goals consistent with the project and for the system. Partners involved focused on sourcing all the necessary local industrials partners and materials providers allowing to finally fabricate and assemble a model of INNOQUA system similar to the experimental one whose efficiency was previously demonstrated in the country. A scenario of local manufacture and furniture sourcing was then provided for each pilot, detailing the capacity of local suppliers and corresponding economic conditions. Different adaptations of the system were assessed to figure out the best scenarios for the efficiency of the system vs. local availability of

materials vs. exploitation potential locally (i.e. cost of the system).The experience gained during the pilot experimentation allowed to evaluate these scenarios considering real data and using the experience as the basis to extrapolate future exploitation scenarios locally.

8.2 Methodology for assessing local sourcing potential

Local sourcing may get different meanings whether the exploitation potential is assessed through different factors. Four scenarios were defined to explore it with the aim to find, in each case, the ideal configuration between performance, price and local manufacture capacity.

- **Scenario 1 (Baseline) – Imported technology**: we use the tanks designed, manufactured and exported by the INNOQUA partner REDI in Italy. The tanks have all the same design and same features, which represent also a technological signature as well as a branding for the project. Tank size is adapted to the requirements of the site in agreement with the available “catalogue” of tanks manufactured by REDI. The MCU is also provided by an INNOQUA partner (EURECAT). The other elements are provided locally.

- **Scenario 2 – Same design, local manufacturing**: The tanks designed by REDI are manufactured by a local plastics processing company (rotational moulding). The initial tank design proposed by INNOQUA is strictly respected to conserve, in the local production, the technological features and the branding associated to the tanks. MCU is also manufactured locally.

- **Scenario 3 – Local sourcing**: We use tanks already available locally, whose design is closed to the original INNOQUA tanks and allows the required adaptation to fulfil with INNOQUA core technology requirements. It means that such tanks must have dimensions and materials that allow the inputs and outputs of water, the installation of the aspersion system, the adequate height for the treatment to be efficient, the possibility to install and maintain the different layers of the INNOQUA system.

- **Scenario 4 – Local manufacturing, local materials**: we use the best available technology on-site, that could mean manufacturing tanks with other materials and adapting the designs when necessary (for example using concrete blocks instead of plastic tanks)

From this initial definition some exceptions were further defined for the local sourcing analysis:

- MCU could be excluded from the assessments as it is defined as a plus for the INNOQUA system, not systematically to be sold with the basic elements. Demo site experience showed that the MCU is a strong asset for the scientific perspective of the project as it eases the monitoring of key factors. However, its added value in a commercial perspective is not demonstrated, at least for exploitation in oversea markets explored during the project.

- UV lamp is a high-tech technology hardly to be provided by other manufacturers in oversea markets, hence the local manufacturing assessment appears not to be pertinent in its case.

- BSP is integrated in oversea demo sites (India and Peru). Hence its integration in the local manufacturing assessment process may be interesting. Moreover, as it is a system based on simple components, a local low-tech manufacturing of the BSP is pertinent.

- Daphniafilter may be more complicated to manufacture locally respecting the initial design. In each country the best scenario of components combination / design simplification for the local manufacturing assessment has to be defined based on demo sites experience.

A first analysis was realised on the potential effects and externalities to be considered for each scenario.

8.2.1 Scenario 1

This corresponds basically to the conditions of the demo sites during the project experimentation period. Hence the prices from this experimentation, although based on an experimental process i.e. with prices for unit by unit production, can be used as a basis for this reference scenario.

8.2.2 Scenario 2

This scenario may generate difficulties for the IP protection as it requires to present complete designs (interior and exterior) to local manufacturers to request for a quotation for manufacturing a local version. Developing countries, where IP protection and respect is generally weaker, present higher risk. A high level of confidentiality is required form the potential providers at this step, using NDA any time it is necessary to share the drawings and mentioning the existing or coming patents underneath each system.

Precise and realistic hypothesis about potential products quantities to be sold in the target country is a must to request quotation about local manufacturing, especially when it implies the creation of new moulds or specific manufacturing lines.

Adjustments in the design can be an option in the case of a local manufacturer having already a manufacturing line that could be used for fabricating INNOQUA tanks with minor modifications (that would be an intermediate scenario between 2 and 3).

8.2.3 Scenarios 3 and 4

The use of locally available products may simplify the replication of the technology and hence also its copy

Design features integrated in the INNOQUA original design for Lumbrifilter and Daphniafilter, and that would have to be integrated in tanks provided locally:

- Inox mesh at the bottom of the tank: can be replaced by a layer of large pebbles
- Aeration: can be insured by holes in tanks walls and the use of a mesh
- Distribution system (Lumbrifilter): the system was improved with demo sites experience and the use of splash plates – a system that is simple, effective and easily replicable locally – was generalised.

Welding of plastic may be tricky and generate further leakages. Hence scenarios 3 and 4 could lead - to a reduction in quality of the product.

It may imply/allow a more decentralised manufacturing, organization, logistic and commercialization scenario than scenario 2

Manufacturing in surrounding countries is also an option if local providers/manufacturers are not available in the target country or are not proposing interesting quality/price offers.

It was concluded that for preventing IP protection issues and potential copy risk in each of the scenarios, it is of primary importance to defend the know-how more than the design itself. Separating knowledge for each provider (not publishing information about layers to someone who may know the tanks design for example) should insure a proper protection.

8.3 Scenario analysis for local sourcing

Local sourcing analysis in Ecuador, India and Tanzania gave the following results (detailed analysis for each site is presented in ANNEX 1).

	India	
	Feasability	**Evaluated costs (Euros)**
Scenario 1 - Imported technology	Important initial manufacturing cost for the tanks	12351
Scenario 2 - Same design, local manufacturing	Stainless steel tanks, original design fully respected. same manufacturing in PE is not available locally or much more expensive	23801
Scenario 3 - Local sourcing	Local plastic tanks adapted to conserve INNOQUA efficiency	6467
Scenario 4 - Local manufacturing, local materials	Cement construction	18672

	Tanzania	
	Feasability	**Evaluated costs (Euros)**
Scenario 1 - Imported technology	Initial manufacting cost of the tank is considerable and resulted doubled by transportation costs and custom fees	23025.56
Scenario 2 - Same design, local manufacturing	Scenario unrealistic for the conditions of Tanzania. It was not possible to find companies able to provide a quotation of rotational moulding unless we could provide a business model for them.	
Scenario 3 - Local sourcing	Plastic tanks	11560.06
Scenario 4 - Local manufacturing, local materials	Concrete tanks	11830.69

	Ecuador	
	Feasability	**Evaluated costs (Euros)**
Scenario 1 - Imported technology	Very high manufacting cost of the tank in Italy, that is further increased by also very high custom fees for importation in Ecuador. For the transport and importation administrative process, more than three months were required	13600
Scenario 2 - Same design, local manufacturing	The few local companies manufacturing aving the required process did not show interest for manufacturing a new product if not in great quantities. They advised to use the tanks already available in their catalogue to get much lower prices.	
Scenario 3 - Local sourcing	Plastic tanks adapted to INNOQUA requirements	826
Scenario 4 - Local manufacturing, local materials	Concrete tanks (NB. this option resulted much more interesting in the case of larger tanks)	793

8.3.1 Considerations in Local Sourcing

The thickness and material of the tanks produced by REDI are of a high quality when they are compared with the local ones (in the case of LDPE tanks). These offer the advantage of burying the tanks without the risk of collapsing, an important characteristic for scenarios where there is not enough space and then the modules should be installed underground. Nevertheless, the price is a limiting factor for the market penetration. In Tanzania a tank with a diameter of 2200mm and a height of 2820mm (more or less the dimensions of the Lumbrifilter used in Tanzania) costs 1000 euros approx. In contrast, the production cost of the Lumbrifilter was 5000 euros. Same figures apply to the case of Ecuador and in both cases the custom fees applied for the importation of the tanks in the country resulted to be highly expensive. A prohibitive price taking into account the purchasing power in the three countries.

In the case of Tanzania, the size of the Lumbrifilter is not competitive with other options already available in the market like septic tanks. To treat 1000L/day a septic tank requires 0.7m2 instead the INNOQUA system (here only Lumbrifilter) occupies near 3m2. A factor relevant in informal settlements were there is a battle for the space due to its limited availability. However, in the case of Ecuador, septic tanks do not allow to comply with local standards, hence the market necessarily required a secondary treatment.

Regarding the MCU, the monitoring and control of the treatment systems are interesting plus, but their development, installation and monitoring are extremely complicated for an environment where a lot of people do not know how to read and/or write. Besides the technical knowledge and the access to sensors, arduinos, etc. is limited and expensive. Additionally, anything that requires electricity is near or close to not work properly due to the constant power cuts faced in the case of Tanzania pilot.

8.4 Optimal Scenario

Considering the limitations observed during the first trial of the INNOQUA system, the only scenario that would be more likely to be implemented in the three countries analysed is the Lumbrifilter. Nevertheless, its design has to be modified somehow in order to cope with the intrinsic limitation of these countries. The Lumbrifilter is more “robust” than other INNOQUA technologies. The filtering materials are accessible and not too expensive, its installation is relatively easy and the operation does not require as much supervision as the Daphniafilter or UV lamp for example. Nevertheless, its size should be decreased and its design modified to match with the local prices of other technologies for wastewater treatment. Besides, a model for Lumbrifilter that does not require electricity supply is mandatory for the conditions in Tanzania and some parts of India. And in the case that pumping is strictly necessary, the niche market will be downsized to places with generators such as hotels, housing developments, offices and maybe some factories.

8.4.1 Feasibility

We face quite different conditions in the three countries assessed. Whereas most of the technologies available in Tanzania and India for wastewater treatment imply manpower and civil constructions (DEWATS, septic tanks, dry toilets, etc.), the most common practice in Ecuador is using cheap plastic septic tanks. The advantage of having a simple tank for the INNOQUA system is that it can be placed almost everywhere as long as the space is available and makes its installation easier.

Price can be lower when using concrete blocks construction in the case of Ecuador, what could lead to a very cheap version of the INNOQUA reduced to a maximum simplicity for very low-income markets.

8.4.2 The Role of the Showcases

Showcases were defined as an onsite demonstration to show the capacity of locally sourced INNOQUA technologies to achieve similar performance as the original imported solution.
A first showcase was implemented in Cuenca, Ecuador, using the resources of the assessment realized for local sourcing on the basis of the pilot site in Quito. Two other showcases are planned to be implemented in Ghana and Sri Lanka respectively

Cuenca, Ecuador

The INNOQUA showcase in Cuenca is installed in the municipal wastewater plant of the city, under the management and control of the INNOQUA partner University of Cuenca. The system is composed by a Lumbrifilter adapted in a 2500 L plastic container used normally as drinking water reservoir. Filter material are pozzolanic stones and gravels and the viable media is made by wood chips and a top layer of earth worms. The filter is being fed with wastewater from the municipal combined sewerage system. Since the influent is diluted, the filter needs larger hydraulic loads to reach enough substrate for worms' metabolism. The systems cost is basically 400 USD and its implementation required an additional USD. First results show good performance of the filter to remove BOD and suspended solids without sludge residuals and showing robustness to high hydraulic loads.

Figure 8-1 INNOQUA showcase in Cuenca

Figure 8-2 INNOQUA showcase in Cuenca

Ghana

The installation of the showcase in Ghana couldn't be done at the date of the first iteration of this document, 31st March 2020 due to the COVID-19 crisis. The showcase is planned to be installed in partnership with the Ghana minister within the GAMA project, a project implementing up to 90 000 sanitation solution in the Accra metropolitan area. The initial contact with the Ghana ministry was made during the World Water Week in Stockholm, 2019, where the consortium have held a dedicated booth to the project.

Sri Lanka

As well as for the installation of the showcase in Accra, Ghana, the installation of the showcase in Colombo, Sri Lanka couldn't be done at the date of the first iteration of this document, 31st March 2020 due to the COVID-19 crisis. The showcase is planned to be installed in partnership with ABC Trading, a society implementing wastewater treatment system in Sri Lanka. The initial contact with ABC Trading LTD was made during the IWA conference in Sri Lanka, 2019, where the consortium have held a dedicated booth to the project.

ANNEX 1

Detailed assessment of local sourcing potential for the INNOQUA system in oversea countries (realized for Ecuador, Tanzania and India):

INDIA

Scenario 1 - Imported technology

We use the tanks designed, manufactured and exported by REDI. The other elements are provided locally

INNOQUA system, Evelyn	Provider	Design	Costs €	Providers	Comments (availability, quality, delay, import issues, differences in technology and design, etc.)
Initial ground preparation, cran	Local	local	1083	BORDA INDIA, CDD and local masons	
Household connection			303	Beedi Community, Nagappa Civil Constructors, Sri Balaji	
Settling tank or septic tank	Local	Local	115	sponsored against small amount by CDD	CDD provided against very small amount a recycled Presettler and Transitions Tank (pumping DF and BSP), usual costs of these two tanks would be around 40.000 as they are big, which allowed to go for gravity outlet. However, if simple pumping tanks could be considered, then price per tank would amount in around 7000 INR, thus around 90€ per tank=180€ total for LF and DF
Pump 1	Local	Local	284	Venus Agencies	
Lombrifilter tank	Imported	Original	4999.97	REDI	not sure on the costs here as received from REDI, have taken prices as indicated by Evelyn
Lombrifilter tank and daphniafilter transportation and custom fees	-	-	xx	Ali sped	was paid by REDI, not sure on final costs as not shared with me
Lombrifilter substrate	Local	Original	573	Local stores	detailed size is hard to get, also specific woodchips, price inclused cocochips and gravel of two sizes
Earthworms	Local		144	Karthik Vermicompost	
Pump 2	Local	Local	119	Venus Agencies	
Daphniafilter tank	Imported	Original	1499	REDI	not sure on the costs here as received from REDI, prices indicated are as to Evelyns calculation
Daphnias	Local				
Plumbing connexions	Local	Local	289	Material by Kaveri, work by BORDA and CDD	
Electrical connexion and MCU installation	Local	Local	2005	JN Tech Solutions	
earthing at site	local	local	98	Omega Electrica	
Electrical backup system, batteries	local	local	838	Aaditya Power Systems	note that inverter was given by CDD, usual costs would be around 30.000 for 3kW, necessary is ~5kW, which would be around 50.000 INR and thus around 1479 for total
MCU, import fees and shipping	Imported	Original	xx	Eurecat	were paid by Eurecat, not sure on final costs as not shared with me
TOTAL			**12351**		

Scenario 2 - local plastic tanks

We use the tanks designed, manufactured and exported by REDI. The other elements are provided locally

INNOQUA system, Evelyn	Provider	Design	Costs €	Providers	Comments (availability, quality, delay, import issues, differences in technology and design, etc.)
Inicial ground preparation, cran	Local	local	1083	BORDA INDIA, CDD and local masons	
Household connection			303	Beedi Community, Nagappa Civil Constructors, Sri Balaji	
Settling tank or septic tank	Local	Local	115	sponsored against small amount by CDD	CDD provided against very small amount a recycled Presettler and Transitions Tank (pumping DF and BSP), usual costs of these two tanks would be around 40.000 as they are big, which allowed to go for gravity outlet. However, if simple pumping tanks could be considered, then price per tank would amount in around 7000 INR, thus around 90€ per tank=180€ total for LF and DF
Pump 1	Local	Local	284	Venus Agencies	
Lombrifilter tank	local	local	513		lumbrifilter plastic tank, 5000l; does only consider a simple tank, no adaptations, pipes, etc. Please note that stability to bury underground would have to be tested (many difficulites on this side)
Lombrifilter substrate	Local	Original	573	Local stores	detailed size is hard to get, also specific woodchips, price inclused cocochips and gravel of two sizes
Earthworms	Local		144	Karthik Vermicompost	
Pump 2	Local	Local	119	Venus Agencies	
Daphniafilter tank	Imported	Original	103		does only consider a simple plastic water tank, without daphniafilter design and overflow.
Daphnias	Local				
Plumbing connexions	Local	Local	289	Material by Kaveri, work by BORDA and CDD	
Electrical connexion and MCU installation	Local	Local	2005	JN Tech Solutions	
earthing at site	local	local	98	Omega Electrica	
Electrical backup system, batteries	local	local	838	Aaditya Power Systems	note that inverter was given by CDD, usual costs would be around 30.000 for 3kW, necessary is ~5kW, which would be around 50.000 INR and thus around 1479 for total
MCU, import fees and shipping	Imported	Original	xx	Eurecat	were paid by Eurecat, not sure on final costs as not shared with me
TOTAL			**6467**		

Scenario 3 - cement construction

We use the tanks designed, manufactured and exported by REDI. The other elements are provided locally

INNOQUA system, Evelyn	Provider	Design	Costs €	Providers	Comments (availability, quality, delay, import issues, differences in technology and design, etc.)
Inicial ground preparation, cran	Local	local	1083	BORDA INDIA, CDD and local masons	
Household connection			303	Beedi Community, Nagappa Civil Constructors, Sri Balaji	
Settling tank or septic tank	Local	Local	115	sponsored against small amount by CDD	CDD provided against very small amount a recycled Presettler and Transitions Tank (pumping DF and BSP), usual costs of these two tanks would be around 40.000 as they are big, which allowed to go for gravity outlet. However, if simple pumping tanks could be considered, then price per tank would amount in around 7000 INR, thus around 90€ per tank=180€ total for LF and DF
Pump 1	Local	Local	284	Venus Agencies	
Lombrifilter tank	local	local	5128		civil construction underground
Lombrifilter substrate	Local	Original	573	Local stores	detailed size is hard to get, also specific woodchips, price inclused cocochips and gravel of two sizes
Earthworms	Local		144	Karthik Vermicompost	
Pump 2	Local	Local	119	Venus Agencies	
Daphniafilter tank	Imported	Original	7692		civil construction with overflow adaptation
Daphnias	Local				
Plumbing connexions	Local	Local	289	Material by Kaveri, work by BORDA and CDD	
Electrical connexion and MCU installation	Local	Local	2005	JN Tech Solutions	
earthing at site	local	local	98	Omega Electrica	
Electrical backup system, batteries	local	local	838	Aaditya Power Systems	note that inverter was given by CDD, usual costs would be around 30.000 for 3kW, necessary is ~5kW, which would be around 50.000 INR and thus around 1479 for total
MCU, import fees and shipping	Imported	Original	xx	Eurecat	were paid by Eurecat, not sure on final costs as not shared with me
TOTAL			**18672**		

Scenario 3 - stainless steel

We use the tanks designed, manufactured and exported by REDI. The other elements are provided locally

INNOQUA system, Evelyn	Provider	Design	Costs €	Providers	Comments (availability, quality, delay, import issues, differences in technology and design, etc.)
Inicial ground preparation, cra	Local	local	1083	BORDA INDIA, CDD and local masons	
Household connection			303	Beedi Community, Nagappa Civil Constructors, Sri Balaji	
Settling tank or septic tank	Local	Local	115	sponsored against small amount by CDD	CDD provided against very small amount a recycled Presettler and Transitions Tank (pumping DF and BSP), usual costs of these two tanks would be around 40.000 as they are big, which allowed to go for gravity outlet. However, if simple pumping tanks could be considered, then price per tank would amount in around 7000 INR, thus around 90€ per tank=180€ total for LF and DF
Pump 1	Local	Local	284	Venus Agencies	
Lombrifilter tank	local	local	7692		civil construction underground
Lombrifilter substrate	Local	Original	573	Local stores	detailed size is hard to get, also specific woodchips, price inclused cocochips and gravel of two sizes
Earthworms	Local		144	Karthik Vermicompost	
Pump 2	Local	Local	119	Venus Agencies	
Daphniafilter tank	local	Original	10256		as to design
Daphnias	Local				
Plumbing connexions	Local	Local	289	Material by Kaveri, work by BORDA and CDD	
Electrical connexion and MCU installation	Local	Local	2005	JN Tech Solutions	
earthing at site	local	local	98	Omega Electrica	
Electrical backup system, batteries	local	local	838	Aaditya Power Systems	note that inverter was given by CDD, usual costs would be around 30.000 for 3kW, necessary is~5kW, which would be around 50.000 INR and thus around 1479 for total
MCU, import fees and shipping	Imported	Original	xx	Eurecat	were paid by Eurecat, not sure on final costs as not shared with me
TOTAL			**23801**		

Please note, in this version the fabrication would be along with the original design and include all elements. For PE it is reported that this cannot be done here and by this the big price differ

TANZANIA

Scenario 1 - Imported technology

We use the tanks designed, manufactured and exported by REDI. The other elements are provided locally

INNOQUA system	Provider	Design	Cost (€)	Providers	Comments (availability, quality, delay, import issues, differences in technology and design, etc.)
Inicial ground preparation	Local		€ 1,383.59	BORDA Tanzania	
Site protection or security guard	Local		€ 993.52	Security guard from surrounding community	A security guard is needed due to the equipments that have been installed in the treatment plant. The costs of the security guard were based on a 8 months operation.
Settling tank or septic tank	Local	Local	€ 802.27	Local masons	
Pump 1	Local	Local	€ 515.80	Davis & Shirtliff	
Lombrifilter tank	Imported	Original	€ 4,999.97	REDI	
Lombrifilter tank and daphniafilter transportation and custom fees	-	-	€ 4,570.68	BOLLORE Italy - BOLLORE Tanzania	Lumbrifilter and daphniafilter were shifted from Italy on February 22nd, 2019 but it was until May 24th that the tanks arrived to Dar es Salaam, Tz. A delay of 3 months
Lombrifilter substrate	Local	Original	€ 450.29	Local stores	
Earthworms	Local		€ 1,736.14	Peter Kanyagia (Kenya)	The earthworms had to be imported from Kenya. The process was extremely long and bureocratic. It was started at the beginning of May and finalized in July 16th.
Pump 2	Local	Local	€ 266.64	Merry water	
Daphniafilter tank	Imported	Original	€ 1,499.99	REDI	
Daphnias	Local		€ -		Local cladocera have been found in Dar es Salaam. But the specie has not been identified. D. magna population has crushed every time we have tried to breed them.
Plumbing connexions	Local	Local	€ 1,460.56	Local masons	
Electrical connexion and MCU installation	Local	Local	€ 2,062.73	Energy +	
MCU, import fees and shipping	Imported	Original	€ 2,283.49	Eurecat	
TOTAL			**€ 23,025.66**		

Scenario 3 - Local sourcing (Tanks in concrete)

We use tanks already available locally whose design is closed to the original Innoqua tanks.

INNOQUA system	Provider	Design	Cost (€)	Provider	Comments (availability, quality, delay, import issues, differences in technology and design, etc.)
Inidal ground preparation	Local		€ 1,383.59	BORDA Africa and Local masons	
Site protection and/or security guard	Local		€ 993.52	Security guard from surrounding community	A security guard is needed due to the equipments that have been installed in the treatment plant. The costs of the security guard were based on a 8 months operation.
Settling tank or septic tank	Local	Local	€ 802.27	BORDA Africa and Local masons	
Pump 1	Local	Local	€ 515.80	Davis & Shirtliff	
Lombrifilter tank	Local	Local	€ 912.38	BORDA Africa and Local masons	Tank in concrete
Lombrifilter substrate	Local	Original		Rattmms General Trading Co LTD	
Woodchips ($4m^3$)	Local		€ 353.94		
Coconut husk ($4m^3$)	Local		€ 278.43		When using coconut husk the color of the water is brown giving a bad impression to the final users
Aggregates ($3.5m^3$)	Local		€ 171.86		It is not possible to find pozzolana in Dar es Salaam or the surrounding areas. Thus, aggregates were and will be used
Earthworms	Local		€ 88.49	Center for Community Initiatives	CCI just started with the earthworms business. Thus, the provision of the product could be unreliable.
Pump 2	Local	Local	€ 266.64	Merry water	
Daphniafilter tank	Local	Local	€ 535.43	Local masons	Tank in concrete, underground
Daphnias	Local		€ -		Local cladocera have been found in Dar es Salaam. But the specie has not been identified. D. magna population has crushed every time we have tried to breed them.
Plumbing connexions	Local	Local	€ 1,460.56	Local masons	
Electrical connexion	Local	Local	€ 2,062.73	Energy +	The installation of the MCU requires high skilled person which in Tanzania is difficult to find, therefore a market penetration should avoid the implementation of a MCU.
MCU	Local	Local	€ 2,283.49	Eurecat	
TOTAL			**€ 11,830.69**		

Scenario 3a - Local sourcing (Lumbrifilter in concrete and Daphniafilter in block works)

We use tanks already available locally whose design is closed to the original Innoqua tanks.

INNOQUA system	Provider	Design	Cost (€)	Provider	Comments (availability, quality, delay, import issues, differences in technology and design, etc.)
Inicial ground preparation	Local		€ 1,383.59	BORDA Africa and Local masons	
Site protection and/or security guard	Local		€ 993.52	Security guard from surrounding community	A security guard is needed due to the equipments that have been installed in the treatment plant. The costs of the security guard were based on a 8 months operation.
Settling tank or septic tank	Local	Local	€ 802.27	BORDA Africa and Local masons	
Pump 1	Local	Local	€ 515.80	Davis & Shirtliff	
Lombrifilter tank	Local	Local	€ 912.38	BORDA Africa and Local masons	Tank in concrete, elevated. Metalic mesh is not included in the price.
Lombrifilter substrate	Local	Original		Rattmms General Trading Co LTD	
Woodchips ($4m^3$)	Local		€ 353.94		
Coconut husk ($4m^3$)	Local		€ 278.43		When using coconut husk the color of the water is brown giving a bad impression to the final users
Aggregates ($3.5m^3$)	Local		€ 171.86		It is not possible to find pozzolana in Dar es Salaam or the surrounding areas. Thus, aggregates were and will be used
Earthworms	Local		€ 88.49	Center for Community Initiatives (CCI)	CCI just started with the earthworms business. Thus, the provision of the product could be unreliable.
Pump 2	Local	Local	€ 266.64	Merry water	
Daphniafilter tank	Local	Local	€ 340.49	Local masons	Tank in blockwork, underground. Metalic wire is not included in the price
Daphnias	Local		€ -		Local cladocera have been found in Dar es Salaam. But the specie has not been identified. D. magna population has crushed every time we have tried to breed them.
Plumbing connexions	Local	Local	€ 1,460.56	Local masons	
Electrical connexion	Local	Local	€ 2,062.73	Energy +	The installation of the MCU requires high skilled person which in Tanzania is difficult to find, therefore a market penetration should avoid the implementation of a MCU.
MCU	Local	Local	€ 2,283.49	Eurecat	
TOTAL			**€ 11,635.74**		

Scenario 3b - Local sourcing (Lumbrifilter and Daphniafilter in plastic)

We use tanks already available locally whose design is closed to the original Innoqua tanks.

INNOQUA system	Provider	Design	Cost (€)	Provider	Comments (availability, quality, delay, import issues, differences in technology and design, etc.)
Inicial ground preparation	Local		€ 1,383.59	BORDA Africa and Local masons	
Site protection and/or security guard	Local		€ 993.52	Security guard from surrounding community	A security guard is needed due to the equipments that have been installed in the treatment plant. The costs of the security guard were based on a 8 months operation.
Settling tank or septic tank	Local	Local	€ 802.27	BORDA Africa and Local masons	
Pump 1	Local	Local	€ 515.80	Davis & Shirtliff	
Lombrifilter tank	Local	Local	€ 983.17	BORDA Africa and Local masons	Tank in plastic, elevated (transport included). Metalic mesh is not included in the price.
Lombrifilter substrate	Local	Original		Rattmms General Trading Co LTD	
Woodchips (4m^3)	Local		€ 353.94		
Coconut husk (4m^3)	Local		€ 278.43		When using coconut husk the color of the water is brown giving a bad impression to the final users
Aggregates (3.5m^3)	Local		€ 171.86		It is not possible to find pozzolana in Dar es Salaam or the surrounding areas. Thus, aggregates were and will be used
Earthworms	Local		€ 88.49	Center for Community Initiatives	CCI just started with the earthworms business. Thus, the provision of the product could be unreliable.
Pump 2	Local	Local	€ 266.64	Merry water	
Daphniafilter tank	Local	Local	€ 194.02	Local masons	Tank in plastic, underground. Metalic wire is not included in the price
Daphnias	Local		€ -		Local cladocera have been found in Dar es Salaam. But the specie has not been identified. D. magna population has crushed every time we have tried to breed them.
Plumbing connexions	Local	Local	€ 1,460.56	Local masons	
Electrical connexion	Local	Local	€ 2,062.73	Energy +	The installation of the MCU requires high skilled person which in Tanzania is difficult to find, therefore a market penetration should avoid the implementation of a MCU.
MCU	Local	Local	€ 2,283.49	Eurecat	
TOTAL			**€ 11,560.06**		

ECUADOR

Scenario 1 - Imported technology

We use the tanks designed, manufactured and exported by REDI. The other elements are provided locally

INNOQUA system	Provider	Design	Cost (€)	Providers	Comments (availability, quality, delay, import issues, differences in technology and design, etc.)
Inicial ground preparation	Local		4027	Local masons	Quite a big work as the site is very tight in urban area and required a reinforced concrete structure
Site protection	Local				
Settling tank or septic tank	Local	Local	183	Plastigama	
Pump 1	Local	Local	100	Kiwi	
Lombrifilter tank	Imported	Original	5000	Redi	
Lombrifilter substrate	Local	Original	164	Landscaping providers	
Earthworms	Local		36	Local agriculture school	
Pump 2	Local	Local	380	imported form France	Pumps available locally do not comply with the requirements for the daphniafilter
Daphniafilter tank	Imported	Original	1500	REDI	
Lombrifilter + Daphniafilter tank transportation and custom fees	-		1659	SENAE	complicated and expensive process
Daphnias	Local		100	sourced in a local lake with the help of a specialist	Not an easy process for a commercial purpose
Plumbing connexions	Local	Local	300	Local plumers	
Electrical connexion	Local	Local	150	Local worker	
MCU	Imported	Original	0	Eurecat	
TOTAL			**13600**		
	Scenario Lombrifilter only:		7592		

Scenario 3 - Local sourcing / focused on a Lombrifilter

We use tanks already available locally whose design is closed to the original Innoqua tanks.

INNOQUA system	Provider	Design	Cost (€)	Provider	Comments (availability, quality, delay, import issues, differences in technology and design, etc.)
Inicial ground preparation	Local			Local masons / separated command	This cost depends directly of the site characteristics and could be: - integrated in building construction costs - reduced to a simple structure in case of using only a lombrifilter
Site protection	Local				
Settling tank or septic tank	Local	Local	183	Kiwi	Plastigama 1100l
Pump 1	Local	Local	100	Kiwi	works with a level detector
Lombrifilter tank	Local	Local	183	Kiwi	Plastigama 1100l
Lombrifilter tank adaptation	Local	Local	40	Local plumbers	No technical difficulty for this adaptation adaptation
Lombrifilter substrate	Local	Original	164	Local landscaping provider	
Earthworms	Local		36	IASA Quito	but also posibility to find in other regions
Plumbing connexions	Local	Local	80	Local plumbers	
Electrical connexion	Local	Local	40	Local electrical technician	
TOTAL			**826**		
	System without settlement tank:		543		

Scenario 4 - Local manufacturing, local materials / Lumbrifilter

We use the best available technology on-site, that could mean manufacturing tanks with other materials and adapting the designs when necessary

INNOQUA system	Provider	Design	Cost	Provider	Comments (availability, quality, delay, import issues, differences in technology and design, etc.)
Inicial ground preparation	Local			Local masons / separated command	This cost depends directly of the site characteristics and could be: - integrated in building construction costs - reduced to a simple structure in case of using only a lombrifilter
Site protection	Local				
Settling tank or septic tank	Local	Local	183	Kiwi	Plastigama 1100l
Pump 1	Local	Local	100	Kiwi	works with a level detector
Lombrifilter tank	Local	Local	150	local construction materials provider	Tank realized with concrete blocks by locally available masons. In this configuration, tank dimension is the smaller one. Assessing the case of larger wastewater treatment requirement with bigger tanks leads to a much lower cost of the concrete blocks based tank than the use of plastic one
Lombrifilter tank adaptatio	Local	Local	40	Local plumbers	No technical difficulty for this adaptation adaptation
Lombrifilter substrate	Local	Original	164	Local landscaping provider	
Earthworms	Local		36	IASA Quito	but also posibility to find in other regions
Plumbing connexions	Local	Local	80	Local plumbers	
Electrical connexion	Local	Local	40	Local electrical technician	
TOTAL (Euros)			**793**		