Deliverable 3.

Updated Watersave+ prototypes design for both zoos

Updated Watersave+ prototype design for zoo Barcelona.

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Content

Introduction

The Life4Zoo project, titled "Water Resources Management in Visitor Attractions - FIT4USE Water Recirculation Technology," aims to provide a technical and environmentally friendly solution through the implementation of a circular water management system (Watersave+). This innovative approach involves low-energy-demanding Natural Based Systems. The project aims to demonstrate the effectiveness of the Watersave+ system in two distinct scenarios: under full-scale real conditions at Liberec Zoo and in a pilot-scale setting at Barcelona Zoo.

The project's proposed actions within Barcelona Zoo are structured into three key areas: water analysis and characterization, the implementation of a nature-based water treatment system, and water recirculation to achieve a closed water usage cycle within the zoo facilities. Specifically addressing water treatment, one of the project's objectives is to design and construct nature-based solution system plants, demonstrating the viability of recovering and recirculating water from zoo facilities through low-cost operation and maintenance treatments.

This document will comprehensively outline the technological scheme of the Watersave+ prototype, detailing the technologies slated for use at Barcelona Zoo, along with material specifications, maps, and figures that were integral components of the documentation for obtaining the construction permit.

Barcelona Zoo

The Barcelona Zoo has approximately 13 hectares and houses about 5,500 animals, featuring over 400 species. It hosts native and exotic species, many of them in danger of extinction, and offers its visitors a unique opportunity to observe animals from all zoological groups. Its main objective is the conservation of biodiversity and its natural habitats through efficient management of water, energy, and waste. In this context, the new model for the Barcelona Zoo aims to both reuse water for cleaning animal enclosures (35%) and replenish water in the pools (24%), offering the advantage of water conservation for irrigation during the peak season.

The recent study at Barcelona Zoo (see deliverable 2) provides a comprehensive analysis of the water quantity and quality; where the total annual water consumption within the zoo amounts to 126,700 m3 and the water quality in animal ponds has a high complexity, delineating significant levels of bacterial contamination, organic matter and nutrients(ammonia and phosphates). It suggests the potential efficacy of natural water treatment solutions, such as treatment wetlands, and grey solutions such as membrane and disinfection processes in mitigating these issues. Wetlands are noted for effectively reducing organic matter and microbial pollution, while membrane technology and disinfection allow for stringent quality to water reuse. This approach aligns with sustainable and ecologically sensitive water management practices, offering a solution that is both effective in pollution mitigation and beneficial to the overall aquatic ecosystem. For that reason, this research aims to develop an integrated hybrid technology of green and grey system to treat the wastewater from the Barcelona Zoo.

The research design allows a comprehensive approach for water treatment of key animal ponds housing species such as pygmy hippopotamus, capybara, stork, Chilean flamingos, carps, spider monkeys, jaguars, crocodiles, and elephants. Animals were selected according to the water consumption per pond, the water quality and the Zoo's interests, as outlined in Deliverable 2. This approach is rooted in identifying opportunities for circular water management strategies to water reuse. Water circularity offers the advantages of reducing the demand for primary water resources, mitigating costs for users, reducing the demand on sewer systems, and having multiple synergies with improved energy and resource utilization. The study underscores the importance of such systems in achieving a balance between the needs of the zoo's inhabitants and the maintenance of water quality.

Objective

This document offers a detailed overview of the preliminary design of the demonstrative pilot conducted as part of the Life4Zoo project at Barcelona Zoo. Specifically, it focuses on developing a flexible nature-based solution to reduce pollution, evaluating its effectiveness across various water sources through three stages: Vertical Subsurface Flow Constructed Wetlands (VSSF), Horizontal Subsurface Flow Constructed Wetlands (HSSF), and ultrafiltration membrane and ultraviolet (UV) radiation. This adaptable design enables the creation of tailored treatment trains specific to each source's water quality and intended use.

The design specifications of the system are elaborated upon in the subsequent sections of this document.

LocationThe prototype will be situated in the area of the ponds housing carp and amphibians at the Barcelona Zoo (41°23′16″N 2°11′28″E), located in the “Ciutat Vella” district, within the metropolitan area of Barcelona (Catalonia) (Figure 1).

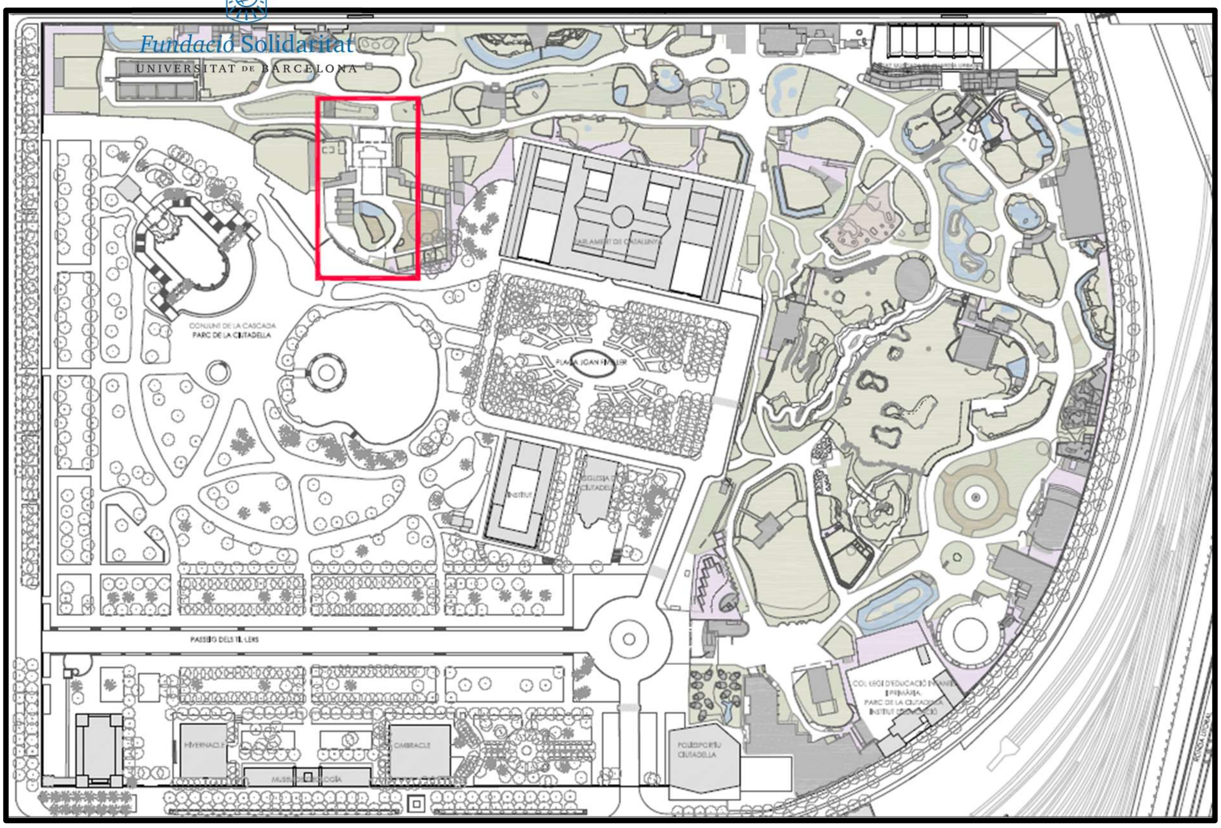


Figure 1. *Location of the construction area at the Barcelona Zoo*

Circular scheme

Wastewater generated by the facilities housing the preselected animals (pygmy hippopotamus, crocodiles, birds, fish, and amphibians) will be treated by nature-based systems consisting of vertical subsurface flow constructed wetlands (VSSF) and horizontal subsurface flow constructed wetlands (HSSF). Subsequently, a refinement system, comprising an ultrafiltration membrane (UF) and ultraviolet radiation (UV). UF treatment will allow for the removal of suspended solids and pathogens, while UV is a disinfection process that guarantees higher log removal of pathogens and viruses.

The system possesses the capacity to concurrently assess various types of water and treatment configurations, facilitating the identification of the most suitable solution to ensure water quality. Configurations may consist of a single stage, such as the vertical wetland, or multiple stages, depending on the quality of the input water. According to the obtained treated water quality, water may be utilized for cleaning animal facilities, irrigation purposes, animal consumption, or filling animal ponds (Figure 2).

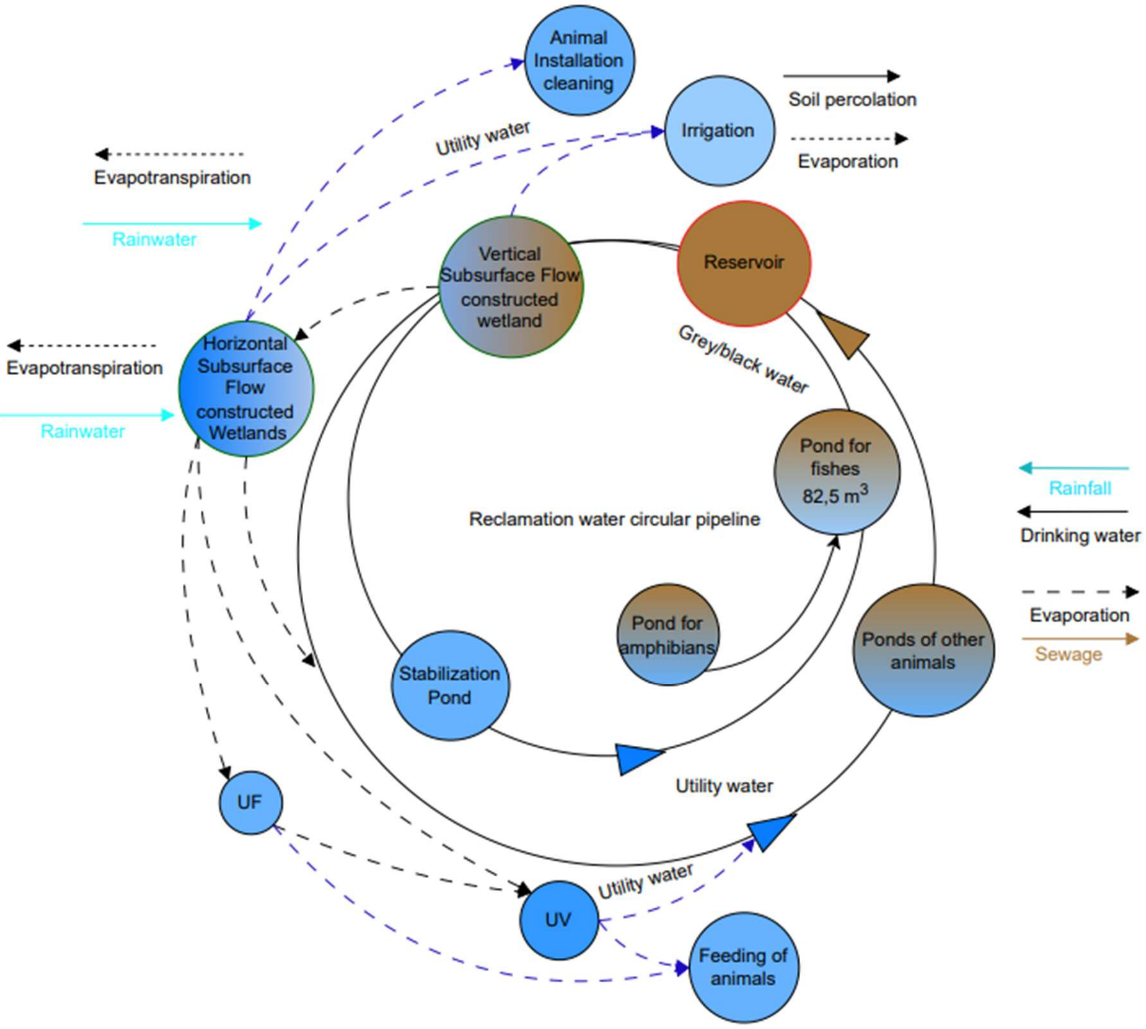


Figure 2. *Circular scheme- FIT4USE water recirculation technology in Barcelona Zoo.*

Preliminary Design

Design parameters

- Vertical subsurface flow constructed wetlands (VSSF): Aeration impact requires fewer square meters per contaminant load, resulting in a smaller footprint. This is an important factor to consider.
- Horizontal subsurface flow constructed wetlands (HSSF): media characteristics.

Operation parameters

- **Treatment Line:** There are viable options to change the treatment line. It includes the application of one stage of VSSF, or combined with other stages.

- **Hidraulic load (HL):** hydraulic load (HL). HL, or hydraulic loading rate (HLR), is the flow applied to the surface of the filter per unit time. It is normally expressed in m/day or cm/day. The HL is inversely proportional to the hydraulic retention time for a given depth, and it varies from site to site and depends on wetland configuration. The HL is one of the foremost factors in performance control for SSFCWs.

- **Organic loading rate (OLR):**

OLR, or organic load, depends on the inlet quality and the HL. OLR is expressed in grams of COD or BOD5 per area (m2) per time (day). VSSF can accept a higher OLR than HSSF. In this context, the pilot plant can treat water with two inlet qualities:

Quality 1 (high pollutant load). This refers to water with a high concentration of suspended solids (SS) and organic matter measured as chemical oxygen demand (COD) (see deliverable 2). This water will be captured in the refrigerated tank to be treated in Line A. It will allow the study of high-organic-load wastewater treatment with natural systems with and without aeration. This will enable us to measure the impact of aeration on the system and the treatment efficiency in degrading complex components (bacteria, viruses, medications) in wastewater.

Quality 2 (low pollutant load). This refers to wastewater with a lower concentration of suspended solids and organic matter (COD). This water will be captured in the refrigerated tank to be treated in Line B. In this scenario, the impact of aeration on the system will also be quantified.

1. **Technological Scheme of the Pilot Plant**

In the overall diagram (Figure 3), a detailed presentation of all elements of the supply, distribution, and connection system of the Barcelona Zoo prototype is provided. The pilot plan is designed to treat two types of water through two separate lines: A and B. Wastewaters originating from specific animal facilities (pygmy hippopotamus, crocodiles, and birds) are directed to a collector tank with a capacity of 200 liters. Subsequently, this tank transports the wastewater to a refrigerated tank with a capacity of 200 liters. Subsequently, a pumping system with a timer that propels water from the refrigerated tank through a pipeline can connect to the first stage of treatment. It involves a system of Vertical Subsurface Flow Constructed Wetland (VSSF) (detailed in the following section):

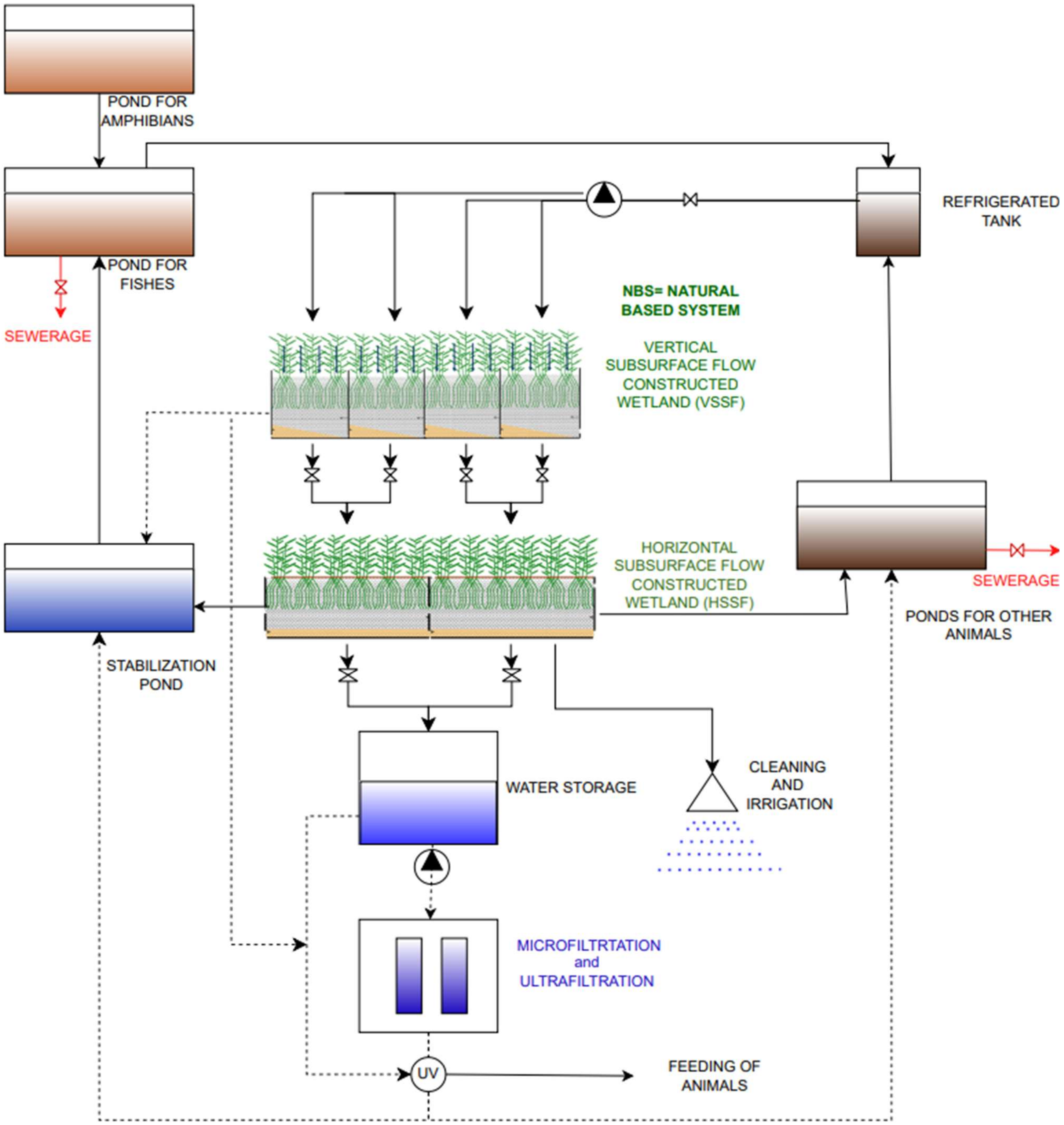
(1) VSSF aerated with coarser materials.
(2) VSSF non-aerated with coarser materials.
(3) VSSF aerated with finer materials.
(4) VSSF non-aerated with finer materials.

Hand valves will direct water to the pilots depending on the type of incoming wastewater. Each filter will have a small outlet chamber with a tap for sampling and the ability to close the outlet pipe. All filters can “close” the circuits.

In the second stage, after passing through the vertical wetlands, a pipeline will convey water to the horizontally aerated subsurface flow wetland with two types of materials (detailed in the following section).

Subsequently, at the outlet of the horizontal wetland, there is a connection system with butterfly valves. In the first pathway, the treated water from the pilot has the option of being discharged to the sewer (to a sanitation chamber). In the second pathway, water is redirected to a tank (200L) connected through a pipeline to the refinement system consisting of an ultrafiltration and/or ultraviolet radiation system. Feeding is controlled by a variable flow pump. At the outlet of the membrane, there is a 3-way connection, where the two flow outlet pathways are connected to mechanical valves. The first pathway allows the collection of samples from the ultrafiltration permeate, while the second pathway enables control of the passage to a UV disinfection system. Finally, the UV is connected to a 3-way connection, where one pathway allows the collection of samples for characterization, while the other pathway has the option of being discharged to the sewer (to a sanitation chamber) or reconnected to the zoo's pond system. Additionally, there is a control, visualization, and recording system. All these elements are described in detail in the following section.

(a)


POND FOR AMPHIBIANS
POND FOR FISHES
SEWERAGE
REFRIGERATED TANK
NBS= NATURAL BASED SYSTEM
VERTICAL SUBSURFACE FLOW CONSTRUCTED WETLAND (VSSF)
HORIZONTAL SUBSURFACE FLOW CONSTRUCTED WETLAND (HSSF)
STABILIZATION POND
SEWERAGE
PONDS FOR OTHER ANIMALS
WATER STORAGE
CLEANING AND IRRIGATION
MICROFILTRTATION and ULTRAFILTRATION
UV
FEEDING OF ANIMALS

(b)

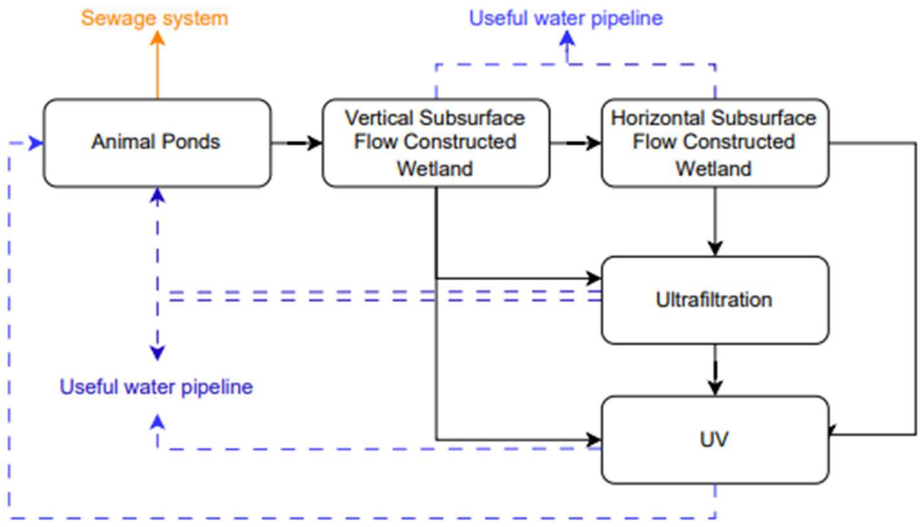


Figure 3. *Watersave+ prototype demonstration in Barcelona Zoo: (a) Technological scheme and (b) Compact block diagram.*

2. Technical Description

a. Water transport system

The PVC water transport tank is mounted on a wheeled cart, facilitating the conveyance of wastewater from the animal facilities to the refrigerated tank, with a capacity of 200 L (Figure 4).

Figure 4. *Water transport system*

b. Refrigerated tank

The Fontsere PF 2 order. II (220V, 50 Hz) refrigerated tank, an open vertical type, contains an electronic temperature control system and a 30-rpm agitation system, enabling the homogenization of wastewater and maintaining its composition for 24 hours. The nominal capacity is 200 liters, with dimensions as follows: 890 x 890 x 990 mm (Figure 5).

Figure 5. *Refrigerated tank*

c. **Pilot plant supply**

A pumping system enables the water's propulsion to the pilots. It is located in a cabinet at the entrance of the vertical wetlands and is connected to a simple on/off programmer. The pump has a flow rate of 0.5x2 m3/h to operate two Vertical Subsurface Flow Constructed Wetland (VSSF) with gravel in parallel. The pump has a flow rate that can handle water with a high concentration of suspended solids (Figure 6).

Figure 6. *Supply pump*

As mentioned earlier, the pumping system can be connected to 4 circuits (vertical wetlands).

d. **Vertical Subsurface Flow Constructed Wetlands (VSSF)**

The vertical filters operate in an unsaturated manner, being filled intermittently before draining out the water. The discharged water is collected in a small sump, primarily designated for sampling purposes and potential horizontal applications (Figure 7).

Each vertical wetland covers an area of 1 m2. Each filter has four layers, as follows:

- Activated Carbon Layer or Other Materials at the Top of the Feeding System (to prevent odors) (approximately 5-10 cm).
- Filtration Layer (with varying thickness between 80 cm and 1 m approximately).
    - V1. Coarser Material (Fine Gravel).
    - V2. Coarser Aerated Material (Fine Gravel).
    - V3. Finer Material (IP Sand).
    - V4. Finer Aerated Material (IP Sand).
- Transition Layer (approximately 10 cm).
- Drainage Layer (with the outlet pipe) (approximately 15 cm).

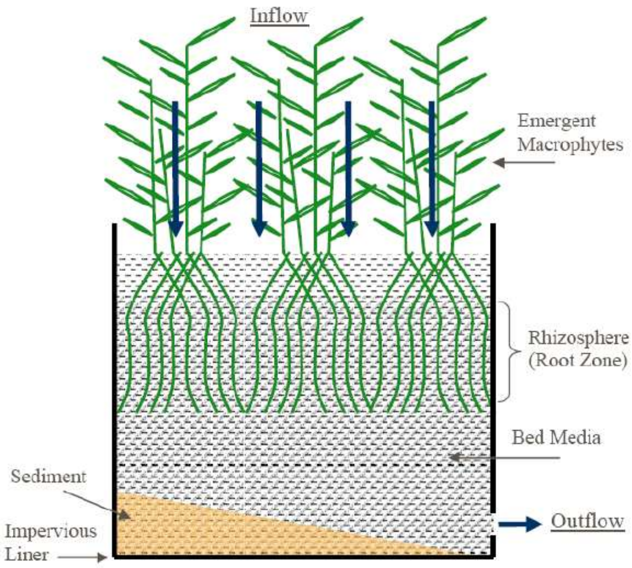


Figure 7. *Diagram of a Vertical Subsurface Flow Constructed Wetland (VSSF)*

e. **Horizontal Subsurface Flow Constructed Wetlands (HSSF)**

Following the vertical filters, a sampling chest is installed, along with a connection to redirect the effluent either by gravity to the horizontal filter or directly to the final treatment stage. All inlet and outlet points of the system are equipped with simple butterfly valves for control purposes.

The two horizontal filters, with a width of 1 and a length of 2.5 meters, operate by gravity, with a slope of at least 0.5%. The height of the gravel or substrate is 60 cm. They have two types of materials, always with an entrance and exit of coarse gravel to aid in distribution and drainage.

Furthermore, the horizontal filters are equipped with an outlet chest featuring a level control device. This chest has an outlet leading either to the storage tank or to the sewage system, the flow of which is regulated by the butterfly valves. All filters can "close" the circuits. A manual valve is placed at each of these branches

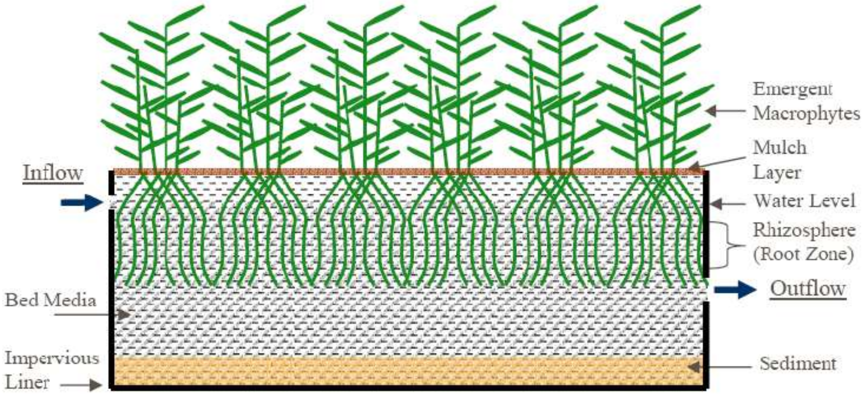


Figure 8. *Diagram of a Horizontal Subsurface Flow Constructed Wetlands (HSSF)*

f. Refinement System

A tank with a capacity of 200 L will collect the water to be treated by the ultrafiltration system, which will feature a pre-filter with a microfiltration membrane. A peristaltic pump, capable of varying flow rates and sustaining pressures up to 10 bars, facilitates the feed to the system. Subsequently, a UV disinfection system with a throughput of 200 L/h is employed for further treatment (Figure 9).

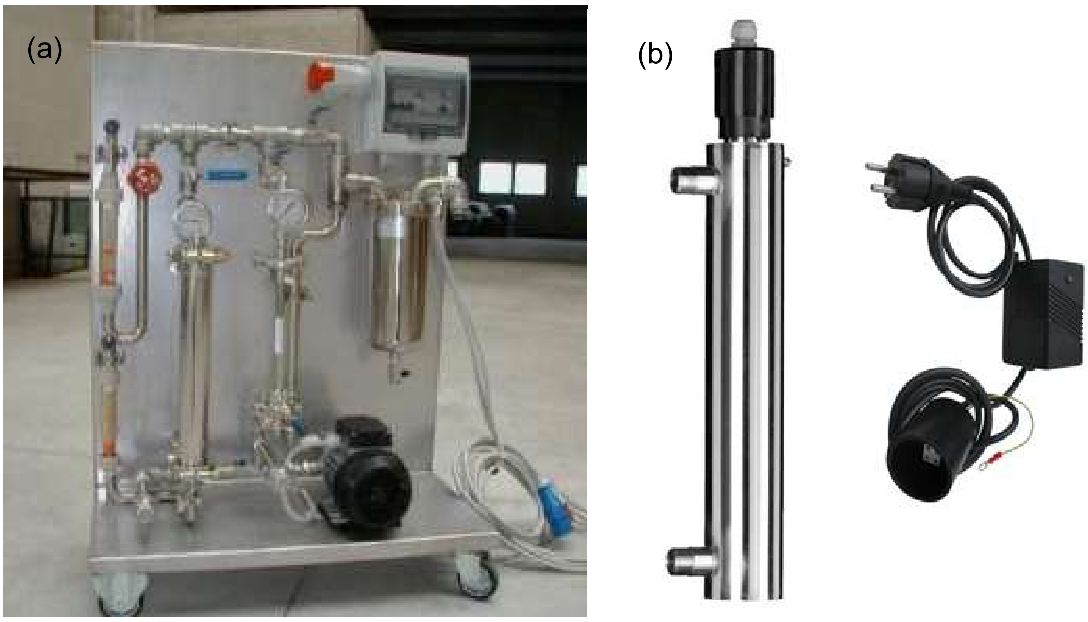


Figure 9. *Refinement system: (a) Ultrafiltration setup and (b) UV disinfection system.*

g. **Control system**

This section defines the control elements of the system. Control elements are crucial for properly functioning, operating, and monitoring the pilot plants. The control system is connected to a data visualisation and recording device (iPod) compatible with Arduino (Figure 10). Sensors (Reference Brand: "DFRobot") are distributed as follows:

- Wetlands (inlet, outlet of vertical wetland, and horizontal wetland): electrical conductivity (3), flow rate (3), pH (3), ORP (3), temperature (3).
- Refinement (inlet and outlet): electrical conductivity (2), flow rate (2), pH (2), pressure (2).

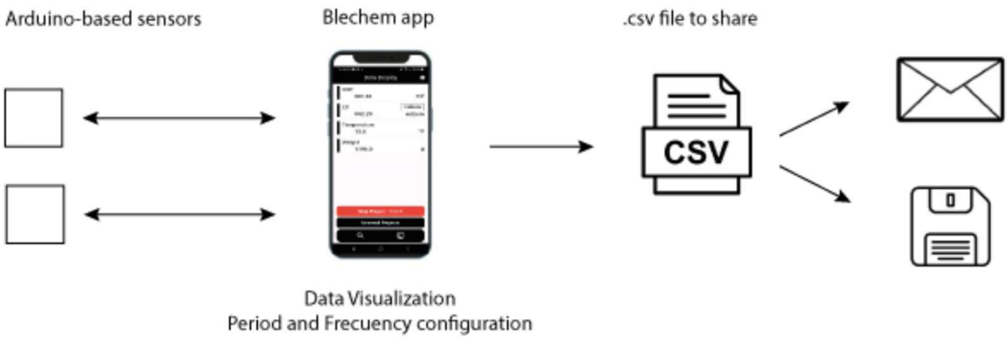


Figure 10. *Structure of the control system (Reference; Blechem app).*

h. **Structures of sample Points**

In addition to the basic analytics monitored by the Arduino system, specific water analytics tests are proposed at the inputs and outputs of the NBSs and the refinement system. Sampling points on line will be integrated to the pilot.

Key considerations

To provide clarification, this report serves as a preliminary design for the forthcoming implementation of the definitive design at the Barcelona Zoo. Presently, the zoo has initiated a public tender process, wherein numerous companies will submit proposals and vie for selection. Following this process, the selected company will undertake the final engineering design within the subsequent months, encompassing comprehensive architectural and electrical considerations.

The terms of the public tender for the Barcelona Zoo are available to the public. You can find the announcement published on the Public Procurement Services Platform (PSCP) at the following link:
https://contractaciopublica.cat/ca/detall-publicacio/8c25c6ef-ee67-4076-a672-209a259010b3/300082471