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Research Article

Proposal for Sewage Treatment at FCT-UL Campus Dondo using Constructed Wetlands

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Abstract

This study aims to address the challenge of poor sanitary sewage management at the Faculty of Sciences and Technology of Licungo University (FCT-UL) Campus in Dondo, by exploring the proposal of Constructed Wetlands as a sustainable solution for sanitary sewage treatment, starting from the observation of the limited capacity for sanitary sewage storage in the existing septic tanks, the research aims to propose a constructed wetlands system for sustainable sewage treatment with landscape adequacy at FCT - UL Campus in Dondo. The methodology adopted included a mixed approach, combining literature review, direct observation, and interviews. The chosen system to be implemented at FCT-UL is the Vertical Flow Constructed Wetlands – French System (VW-FS), planted with Typha Latifolia or Tifton 85 Grass operating with two units in parallel. Input data for the system, including the average water flow and the equivalent population of FCT-UL, were used for the definition of sizing criteria. The criteria were based on the hydraulic surface application rate. The final design resulted in a Surface Area of 16 m^2 for the first stage, 8 m^2 for each unit with a height of 70 cm. The filtering material of the system consists of 2 - 6 mm in the filtering layer, 5 - 20 mm of gravel No.1 in the transition layer, and 20 - 60 mm of gravel No.3 in the drainage layer. It is concluded that the WV-SF chosen in the project is an efficient and sustainable alternative for the treatment of sanitary sewage at FCT - UL Campus of Dondo, with a high average removal efficiency of TSS, BOD, COD, TKN, and NH_4^+.

Introduction

The concern regarding the lack of sewage treatment is associated with the environmental impacts resulting from the release of high organic load, high concentrations of ions and solid materials, in addition to the possibility of the presence of toxic elements [1,2], which can lead to a reduction in the levels of Dissolved Oxygen (DO) in the water, microbiological contamination of the receiving bodies , increased supply of nutrients (phosphorus, nitrogen), favoring the occurrence of eutrophication and, consequently, a reduction in water quality, in addition to the loss of aquatic biodiversity [3,4].

The first records of the use of Constructed Wetlands (WCs) in the treatment of sewage date back to 1970 in Europe. Since then, these systems have been extensively used worldwide, demonstrating high efficiency, including in the post-treatment of industrial effluents and in the treatment of gray water, especially in tropical regions. In the second half of the 1990s, Brazilian universities began publishing the first master's studies that explored various types of constructed wetlands for the treatment of sewage and wastewater of various origins. Most of these studies were conducted on a pilot scale, as defined by Rodriguez- Dominguez, et al. [5], comprising a unit installed close to the generating source and receiving real wastewater to assess treatment performance, regardless of scale.

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In this context, the general objective of this research is to propose a system of constructed wetlands for the sustainable treatment of sewage with landscape suitability in the FCT - Dondo Campus; and specifically, it was intended to dimension a system of constructed wetlands for the treatment of sewage in the FCT-UL; contribute to sustainable solutions for the treatment of sewage by improving its sustainable use in the FCT-UL in Dondo;

The choice of this theme is the result of a detailed observation of the lack of a sustainable sewage treatment system, as well as the limited sewage storage capacity in septic tanks, which results in the constant overflow of sewage from septic tanks at the FCT-UL Dondo Campus facilities. This situation raises serious concerns about the preservation of water resources and the public health of users (students, teachers and CTA). Furthermore, considering that the FCT-UL Dondo Campus lacks landscaped areas, the opportunity arises to explore the reuse of water to create a greener environment, promoting the aesthetic and ecological revitalization of the institution. In this context, the justification for this study is rooted in the urgent need to propose a sustainable sewage treatment system in FCT-UL, in line with the principles of environmental conservation and responsible use of water resources, requiring a comprehensive approach to deal with liquid waste in a sustainable manner.

The two septic tanks currently existing at the FCT-UL Dondo Campus are inadequate to handle the volume of sewage generated by the institution, resulting in a series of problems, including negative impacts on the environment, as observed in the courtyard; sewage overflows from the septic tanks, generating a bad smell in the surrounding area, especially near the cafeteria and the Chemistry laboratory, as illustrated in Figure 1, which can contribute to the spread of diseases and affect the integrity of the environment; uncontrolled growth of grass around the septic tanks; contamination of the water table and high costs for external removal by means of sewage suction trucks, implying the payment for the systematic emptying of the septic tanks. All of this results in an unsustainable treatment of sewage, compromising the aesthetics of the institution's landscape (FCT). Given this challenging context, the following guiding question for this research arises: *"What type of wetlands should be used to treat sewage?" built can be implemented in the facilities of the FCT – UL Campus of Dondo, aiming at the sustainable treatment of sewage and landscaping adaptation of the enterprise?"*

Theoretical basis

Types of wetlands

Wetlands can be natural and constructed.

Natural wetlands are environments characterized by the transition between an aquatic ecosystem and a terrestrial ecosystem, and may be flooded for short periods or constantly. Wetlands are popularly known as marshes, swamps or marshes, but can be defined as impact buffer zones.

Wetlands built (WC) also known as constructed wetlands, filters planted with macrophytes or constructed wetlands, are artificial wetland systems developed to treat wastewater, mainly from sanitary sewage. These systems are designed to use aquatic plants and microorganisms to control water pollution, improving its quality. Constructed wetlands were designed to take advantage of the assimilation and conversion capacity of organic matter (carbon) and nutrients (nitrogen and phosphorus), as occurs in natural wetlands [6].

Classification of constructed wetlands

Wetlands are classified according to the level of the water column: they can be surface runoff and subsurface runoff, the latter being divided into horizontal or vertical subsurface runoff, depending on the direction of the fluid flow (Figure 2).

Constructed Runoff Wetlands (WCS): When present, the support medium (substrate) remains saturated and with water flow flowing across the surface, that is, above the support material. WCS have favorable conditions for the development of several species of aquatic macrophytes, which can be floating, submerged or emergent. The effluent to be treated is distributed homogeneously on the surface of the bed, flows horizontally and superficially, with a water depth of around 0.5 m and low flow velocity. The treated effluent is collected by drainage pipes located at the bottom of the support material. It is noteworthy that this system operates with continuous effluent feeding [6] (Figure 3).

Figure 1: Image of a septic tank overflowing with sewage at FCT-UL, Dondo Campus, March 2024.
Source: Author 2024 [10].

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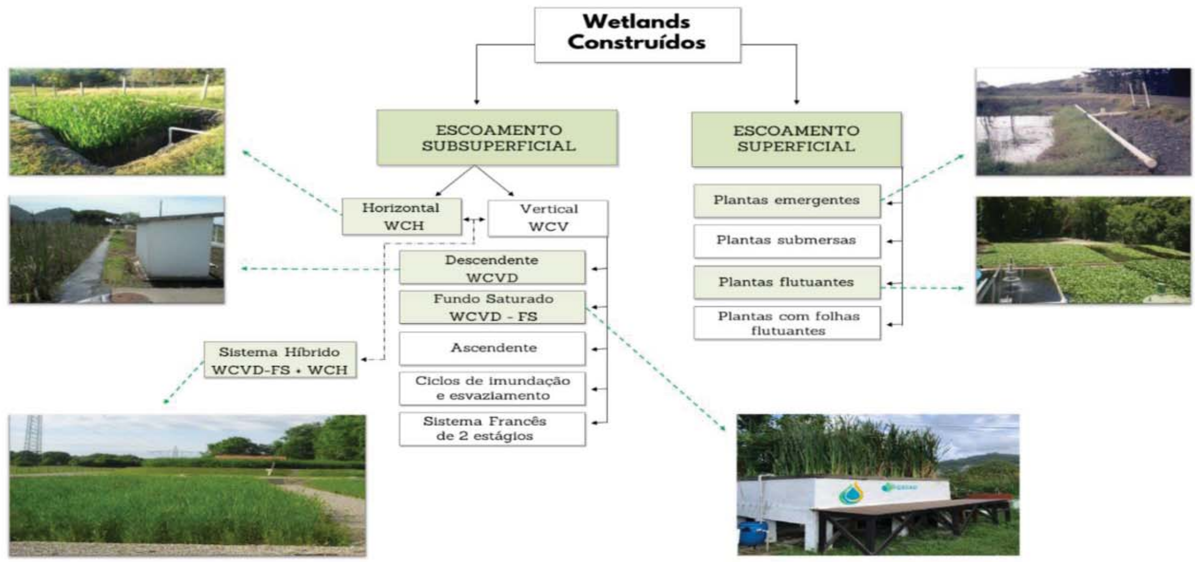

Figure 2: Constructed wetlands classification scheme and images.
Source: Sezerino et al. [7].

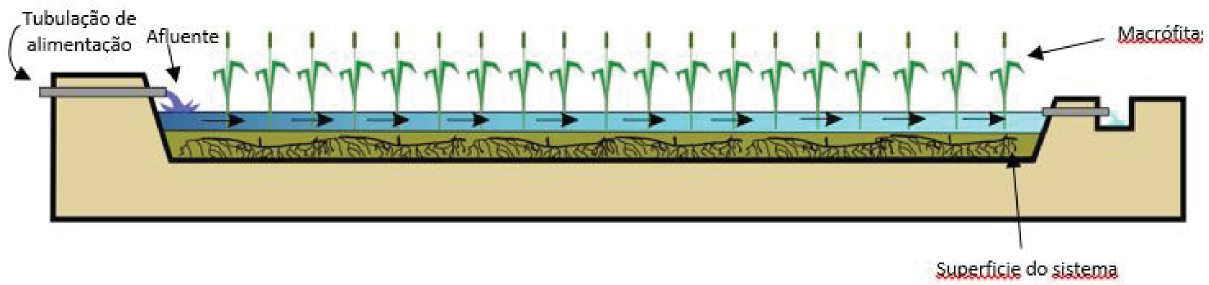

Figure 3: Schematic drawing of wetlands surface flow constructions (WCFS).
Source: Salati [15].

Horizontal Subsurface Flow Constructed Wetlands (CHW): Subsurface flow constructed wetlands (WCH) are modules excavated in the soil, or built under it, with waterproofed sides and bottom, filled with filtering materials whose physical indices (distribution of grain diameters, uniformity and porosity) favor flow, from where the distribution pipes of the inflowing sewage and collection of the treated sewage are arranged on opposite sides in order to provide a horizontal longitudinal flow, favored by a bottom slope, and planted with emergent macrophytes , as schematically represented in Figure 4 [7].

Wetlands Vertical Subsurface Flow (WCV) Constructions: These WCV modules are also excavated in the ground, or built under it, with waterproofed side and bottom walls, filled with a filter material with high hydraulic permeability, with the influent sewage supply pipe laid under the surface of the filter and the treated sewage collection pipe, also called drainage pipe, laid at the bottom of the reactor. The macrophytes are transplanted on the surface of the filter bed, and the treated sewage will percolate across the entire surface, tending to vertical flow that will pass through the rhizosphere – the region of contact between the root system of the macrophytes and the filter mass [7] (Figure 5).

Wetlands vertical flow constructions – Conventional French System (WV – SF): This technology is applied in the treatment of raw sewage, that is, it does not require a prior primary treatment stage (septic tank or Imhoff tank), which facilitates sludge management [7-9], since effluent treatment and sludge stabilization occur in the same system. Due to its ease of operation and good contaminant removal capacity, WV-SF has gained a good reputation in the treatment of domestic sewage, and is currently the most widely used system in France for application in small communities [7,8] (Figure 6), being commonly implemented in population clusters of up to 2,000 individuals, complying with the standards, with construction adaptations, the recommendations of France by the team of the National Institute of Research in Science and Technology for the Environment and Agriculture (Inrae), formerly IRSTEA (*Institut National Research Council en Sciences and Technologies for Environment and l'Agriculture* , in French) and Cemagref (*National Centre of Agricultural Mechanization* , *Agricultural Engineering* , *Water and Forests* , in English).

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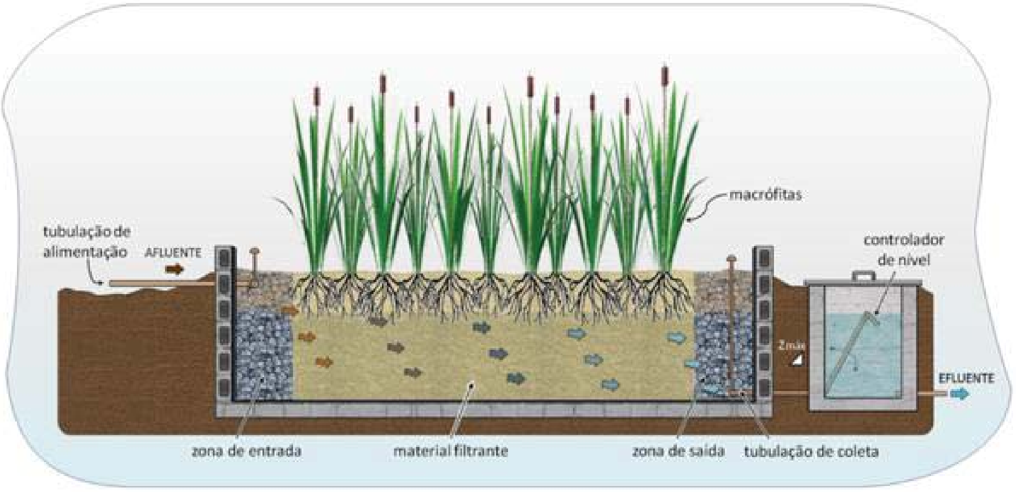

Figure 4: Representative diagram of a longitudinal profile of the horizontal subsurface flow constructed wetland – WCH.
Source: Sezerino, et al. [7].

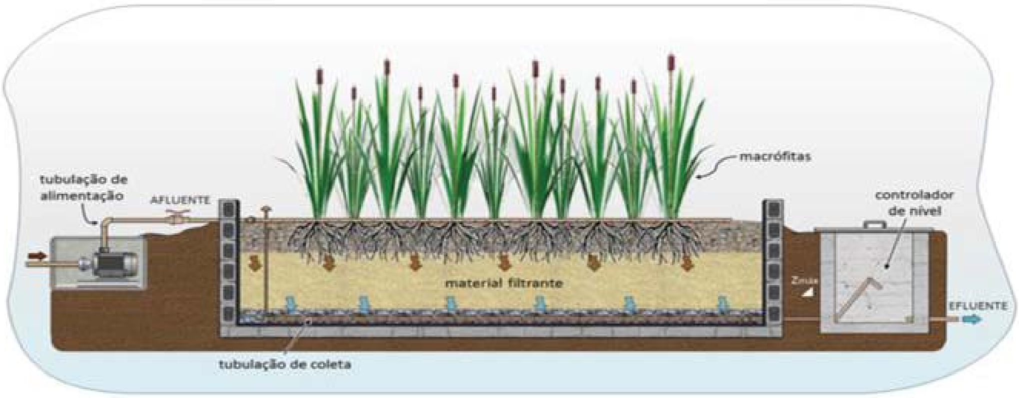

Figure 5: Representative diagram of a vertical profile of the constructed vertical flow wetland – WCV.
Source: Sezerino, et al. [7].

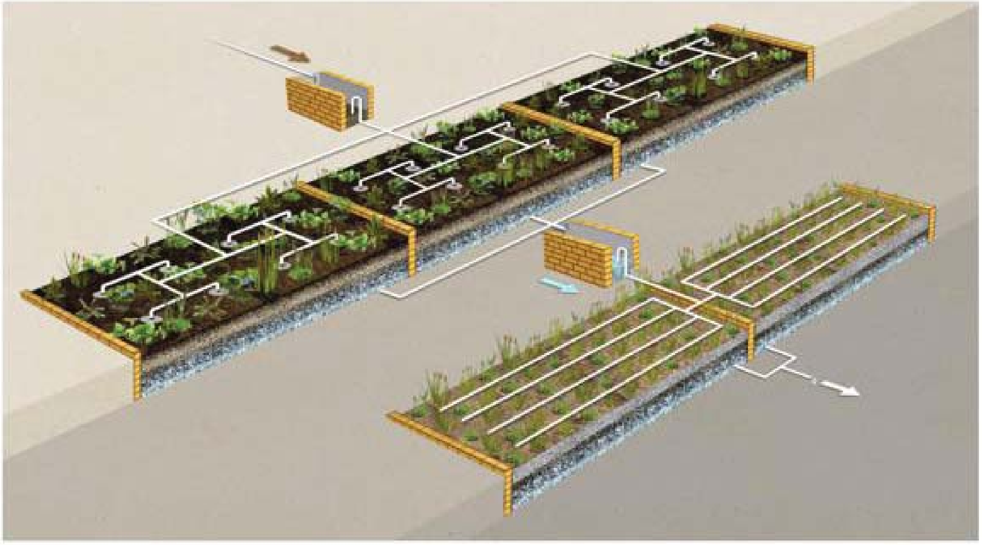

Figure 6: Diagram of a vertical wetland – Traditional French System: Three units in the first stage and two units in the second stage.
Source: Sezerino et al. [7].

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Construction stages of community-constructed wetlands

The development and implementation of constructed wetlands (WCs) in a community involves several fundamental steps. Initially, a detailed assessment of the site is carried out, considering factors such as topography, soil and climate. Based on this analysis, the most suitable type of WC for the area is defined, whether horizontal flow, vertical flow or other variations. The next step involves sizing the WC, determining the dimensions, depths and surface area required for effective treatment. In parallel, the choice of filter materials, such as crushed stone and gravel, is crucial to ensure efficient removal of pollutants.

After detailed planning, the physical construction of the WC begins. Excavation of the designated area is carried out, followed by the installation of filter layers, such as crushed stone, gravel and sand, strategically positioned to optimize treatment. The introduction of selected plants, such as Typha latifolia and other recommended species, contributes to the stabilization and efficiency of the system.

Research methodology

Description of the study area

UniLicungo – Dondo campus, faculty of science and technology: The study area where the research took place is located in the city of Dondo, in the province of Sofala, on the national road number 6, with the specific address: 8QRG+HH at UniLicungo – Dondo Campus, Faculty of Science and Technology with more than 3500 students. Dondo is located in a humid tropical climate. Throughout the year, the temperature generally varies from 18 °C to 31 °C and rarely below 16 °C or above 35 °C [10] (Figure 7).

Project layout design

Layout was developed, specifying the dimensions of the length, width and depth (height) of the system. The layout reflected the physical characteristics of the deployment site, including potential areas identified during direct observation of the study site.

Filter materials and plant types: A detailed proposal for the filter materials to be used was drawn up, considering the efficiency in removing specific pollutants identified in the literature review. In addition, suitable plant types were suggested to optimize the treatment process.

Plant selection focused on adaptability and treatment efficiency. **Typha latifolia** (cattail) was chosen for its strong root system and oxygen transfer, while **Tifton 85 grass (Cynodon dactylon Pers.)** was selected for rapid growth and tolerance to tropical conditions. Both species thrive in Dondo's 18 °C - 31 °C climate, ensuring stable year-round operation. The French vertical-flow system (WV-SF) was adopted as it treats raw sewage and stabilizes sludge in the same bed, reducing desludging frequency and operational costs. The tropical climate, with high sunlight and natural aeration, further supports plant growth and accelerates organic decomposition, enhancing pollutant removal efficiency.

Power and circulation system: A practical system was developed for feeding sewage into the Wetland and circulating it efficiently to maximise treatment efficiency. This included details on the routing of sewage to the Constructed Wetland system and the arrangement of plants to optimise nutrient removal.

System sizing

The proposed wastewater treatment system at the FCT-UL Dondo Campus is the Constructed Wetland Vertical Flow – French System (WV-SF). This specific model was chosen due to its unique ability to treat sanitary sewage in its raw state, eliminating the need for primary (septic tank) or secondary treatment, a particularly advantageous feature when compared to other horizontal and vertical wetland systems. Given the tropical nature of the climate at FCT-UL, characterized by

Figure 7: Septic tanks at the FCT-UL Dondo Campus facilities.
Source: authors' observation 2024 [10].

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temperatures ranging from 18 °C to 31 °C and rarely falling below 16 °C or exceeding 35 °C , the WV-SF will be operated in a single stage, configured with two parallel modules, one in feed and the other in standby mode in an alternating manner.

System sizing criteria

To design the WV-SF system, data provided by the Head of Assets and Logistics of the FCT corresponding to the months of January and February were used in relation to the volume of water used during these last months. On the one hand, the population number was provided by the academic registry. The system was designed for a population of 3500 inhabitants. The volume of water consumed was 88 m^3 /month for the month of January and 120 m^3 /month for the month of February, an average of 3.5 m^3 /d. The flow value used was 3 m^3 / d.

Although monthly averages indicated a flow of ~3.5 m^3/day, a value of 3 m^3/day was adopted as a design criterion to ensure operational flexibility and account for fluctuations, with the system capacity allowing for moderate variations in daily inflow.

Surface area

The total area of the system was 16 m^2 for an average flow rate of 3 m^3 / d. With two units in parallel, each with a surface area of 8 m^2 (width of 2 m and length of 4 m) as illustrated in Figure 8. If there is a need to obtain a better quality effluent, it is possible to insert a post-treatment consisting of horizontal flow wetlands with landscape adaptation, with the same surface area of 8 m^2 that will polish the treated water in the first 2 modules.

Filter materials

The filtration system is composed of three overlapping layers measuring 40 cm of sand layer (2 - 6 mm), followed by a second layer of gravel (5 - 20 mm) and a third layer of gravel (20 - 60 mm), that is, with increasing granulometry from the surface: filtering layer, transition layer and drainage layer, as illustrated in Figure 9. The filtering material selected for each module, whose granulometry is detailed in Table 1.

Operating and power system

The Wetland Constructed Vertical Flow – French System (WV-SF) will adopt an efficient 24-hour batch flow operation method for treating sewage. This innovative system is designed to optimize treatment efficiency while promoting ideal conditions for biological decomposition. Key features of the system include:

a) **Batch Flow Operation:** The WV-SF operating cycle is based on alternating feeding and resting phases, each lasting 3.5 days, 7 days in total. During the feeding period, a batch of raw sewage is applied, covering the filter surface with a liquid layer between 2.5 and 5 cm, as recommended by Lombard Latune and Molle [11-13]. This approach aims to optimize treatment efficiency by providing ideal conditions for biological decomposition. The system will be fed through siphons, eliminating energy expenditure and allowing efficient transportation of raw sewage from the septic tank to the WV-SF bed.

b) **Types of plants for constructed wetlands:** According to Cota [14], the most recommended species is *Typha latifolia, popularly known as Taboa and Tifton 85* grass (*Cynodon dactylon Pers.*) which adapts to the temperature and humidity conditions of the area.

Monitoring

The operation of the WV-SF is directly related to the influent to the system, so it is essential to monitor its physical-

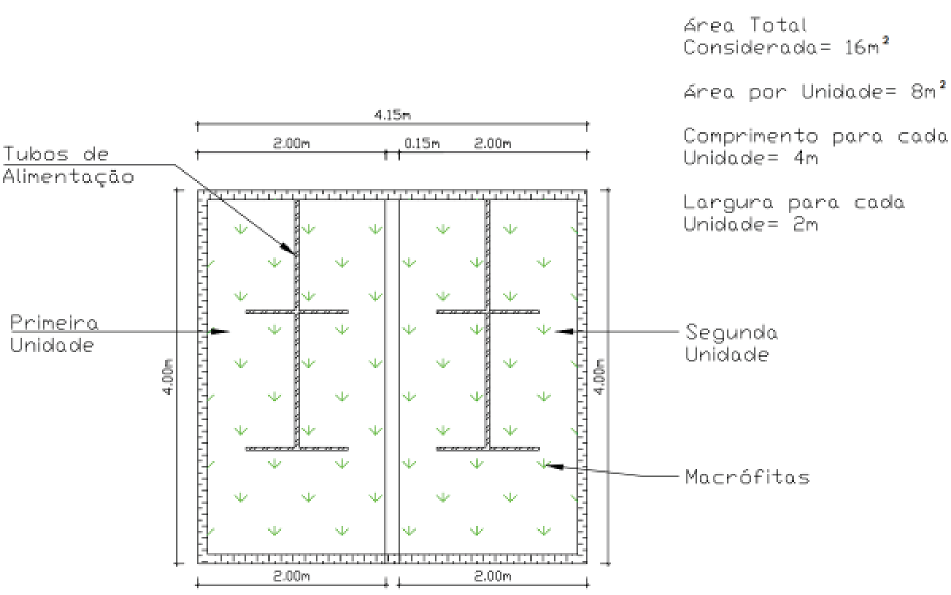

Figure 8: Top view of the proposed project plan.
Source: Authors' proposals 2024 [10].

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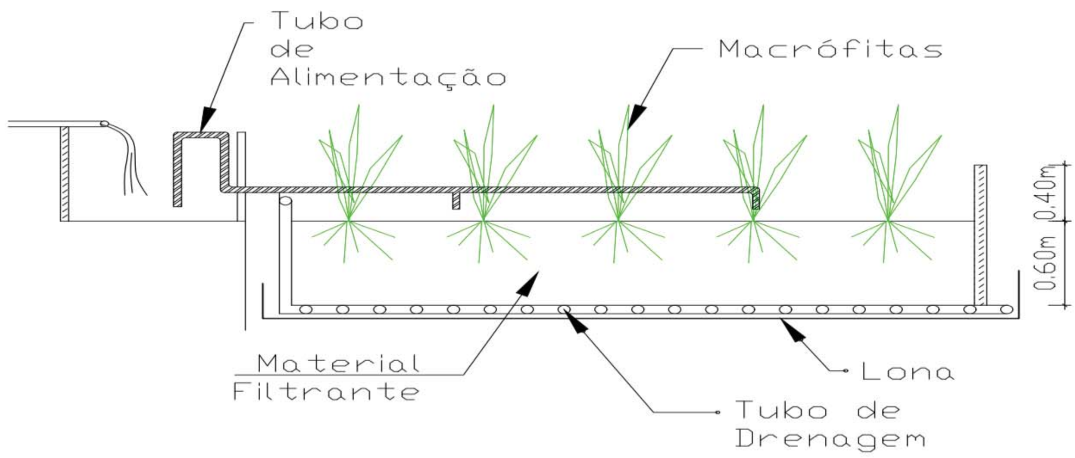

Figure 9: Front sectional view of the proposed project.
Source: Authors' Proposal 2024 [10].

Table 1: Height of layers and granulometry of filter material.

Layer	Height	Material granulometry
Filter	40 cm	Area (2-6 mm)
Transition	30 cm	Gravel (5-20 mm)
Drainage	30 cm	Gravel (20-60 mm)

chemical characteristics, always adopting corrective measures in the treatment system prior to post-treatment if necessary. The factors that should always be monitored are: Biochemical Oxygen Demand (BOD); Chemical Oxygen Demand (COD); Total Kjeldahl Nitrogen (TKN); Ammoniacal Nitrogen ($N\text{-}NH_4^+$); Suspended Solids (SST); pH and Temperature [15-41].

Conclusion

Considering the aspects addressed in this research, it is concluded that the Constructed Wetlands System with Vertical Flow – French System (WV-SF) operating with only a single stage, configured with two units in parallel, is a solution for the sustainable treatment of sanitary sewage at the FCT-UL Campus in Dondo. The choice of WV-SF as a solution reflects its ability to integrate harmoniously with the environment, creating green spaces that not only treat sewage, but also aesthetically revitalize the landscape of the FCT-UL; Considering the comprehensive nature of the project as a whole, it takes into account the natural conditions (such as sunlight and ventilation) that may affect the landscape design, including the effectiveness of the treatment of WCs; Meeting the aesthetic aspects and interaction with the surroundings , the objectives of the project are clearly defined, which will allow the reduction of costs in the sewage treatment, since there will no longer be a need to pay for emptying septic tanks.

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