Case Study: Decentralized wastewater treatment at a Brazilian University

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Highlights:

·Importance of environmental adequacy in Higher Education Institutions (HEI).

· Effective microbiological removal even at the beginning of operation.

· Aerobic Spore-forming bacteria has been applied to evaluate the disinfection efficiency.

· Effluent with suitable characteristics for reuse.

Keywords: Constructed Wetlands; indicator microorganisms; water reuse.

INTRODUCTION

Decentralized wastewater treatment systems, as opposed to traditional centralized systems, involve the collection, treatment, and final disposal or reuse of wastewater in close proximity to its point of generation (Tonetti et al., 2018). These systems stand out for several advantages, including reduced implementation costs and contributions to local sustainability (Tonetti et al., 2018; Metcalf and Eddy, 2016).

Higher Education Institutions (HEI) play a fundamental role not only in disseminating knowledge but also as examples of environmental adaptation. In this context, due to numerous impacts related to poorly treated domestic effluents, a decentralized wastewater treatment plant (DWWTP) was proposed and built for treating domestic wastewater from student residences, called the University Student House, on the UFSM *Campus* in Frederico Westphalen, Rio Grande do Sul, Brazil.

The utilization of a screenig, septic tank, pump station, along with four vertical flow constructed wetlands (VFCW) transplanted with *Canna x generalis*, and disinfection by ultraviolet radiation, has resulted in treated effluent with satisfactory physicochemical and microbiological characteristics. This effluent is suitable for potential in situ reuse in the future.

METHODOLOGY

The DWWTP was designed to treat the domestic effluent of approximately 72 people that live in the University Student House. To size the septic tank, the criteria of Standard ABNT NBR 7229 (BRASIL, 1993) were followed. Regarding VFCW, the criteria and information from Von Sperling and Sezerino (2018) were followed. The disinfection stage using UV radiation, with emerged lamps, was designed according to Metcalf and Eddy (2016). After budget pre-approval, adjustments to the space of the future DWWTP and hydraulic criteria were fundamental for the final design.

The following physical-chemical quality parameters of the effluent are monitored: pH, temperature, flow rate, apparent color, turbidity, solids, nitrogen, and COD, following the guidelines outlined by APHA et al. (2017). In terms of microbiological, total coliforms (TC) and *E. coli* are quantified, using the Colilert® and Quanti-Tray 2000® methods, while aerobic spore-forming bacteria are quantified using the membrane filtration method on specific media, such as Nutrient Agar with Tryphan blue (APHA et al., 2017).

RESULTS AND CONCLUSIONS

After its completion, the DWWTP started operating in August 2023, as depicted in various stages in Figure 1.

Figure 1. Decentralized wastewater treatment plant: Construction (A-B) and Operation (C – after 30 days; D – after 90 days; E – after 120 days) 1. Septic Tank and Pump Station; 2. VFCW; 3. UV unit.

Key features of the treatment units include a septic tank with two chambers: the first measuring 2.41 m of length, followed by the pump station with 1.62 m of length, and both chambers with the same width (1.22 m) and depth (2.32 m). Each VFCW has an area of 23.8 m². The two VFCW units (W1 and W2) that have fine sand as the principal bed layer alternate operation with cycles of 3 days for rest and feed periods, while the two units with gravel (W3 and W4) operate continuously. They also differ due to the saturation level (0.15 and 0.25 cm).

Some of the main physical-chemical removal efficiencies achieved the fine sand and gravel are, respectively: 75% (W1), 80% (W2), 64% (W3), 69% (W4) for COD, and 59% (W1), 56% (W2), 34% (W3), 39% (W4) for $N\text{-}NH4^{+}$. In terms of microbiology, the DWWTP typically removes and/or inactivates an average of 1.5 and 2.0 logs of total coliforms and *E. coli*, respectively (Figure 2). Additionally, aerobic spore-forming bacteria demonstrate high resistance to UV radiation and achieve an average of 0.32 log inactivation.

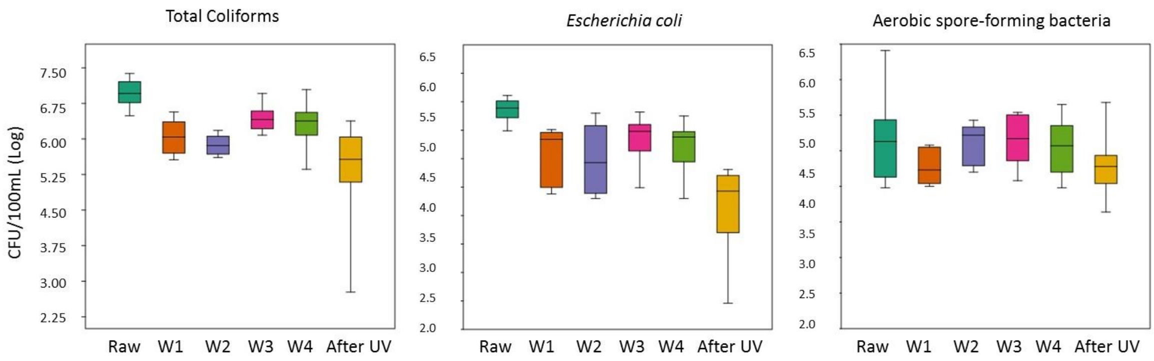

Figure 2. Microbiological removal through DWWTP (W1 and W2 – sand; W3 and W4 – gravel).

In specific cases such as this, the integrated approach of teaching, research, and extension has been important since the project's inception. Regarding teaching, the DWWTP serves as a practical resource for both basic and applied disciplines at both undergraduate and postgraduate levels.

The preliminary sizing study was conducted based on an undergraduate final project. Subsequently, a master's thesis has been defended, along with another final assignment and presentations at national scientific conferences, all featuring DWWTP monitoring data. Furthermore, there are currently three ongoing master’s dissertations and three undergraduates’ final projects.

Extension activities on campus include welcoming visits from primary and secondary school students, with the DWTP serving as a focal point for raising environmental awareness and emphasizing the importance of basic sanitation practices. Notably, the project integrates innovative elements, such as real-time monitoring of the pumping station through a dedicated application, involving the Information Systems field. Furthermore, in alignment with the principles of the circular economy, the project has initiated the reuse of disinfected effluent for irrigation purposes, thereby connecting the fields of Agricultural and Forestry Sciences.

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