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Initial Operation of Full-Scale Partially Saturated Vertical Flow Constructed Wetlands at a Brazilian University

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Highlights:

- Monitoring results of a real-scale PS-VFCW system.
- High removal efficiencies even in the early stages of operation.
- Study subject for various knowledge areas.
- System aligned with sustainable development and circular economy.

Keywords: Partially Saturated Vertical Flow Constructed Wetlands; Decentralized Wastewater Treatment; Sustainable Development.

INTRODUCTION

Decentralized wastewater treatment systems are crucial for advancing basic sanitation in developing countries such as Brazil (Tonetti et al., 2018). These systems must be aligned with the principles of sustainability and circular economy, meeting the technical and sociocultural needs of their installation sites.

Vertical flow constructed wetlands (VFCW), especially the partially saturated ones (PS-VFCW) are a very promising technology aligned with United Nations Sustainable Development Goal number 6 (Clean Water and Sanitation) (UNITED NATIONS, 2021). This type of system, besides being easy to operate and requiring low maintenance, allows the use of treated effluent and other by-products, and acts as an agent of harmony and landscape ornamentation.

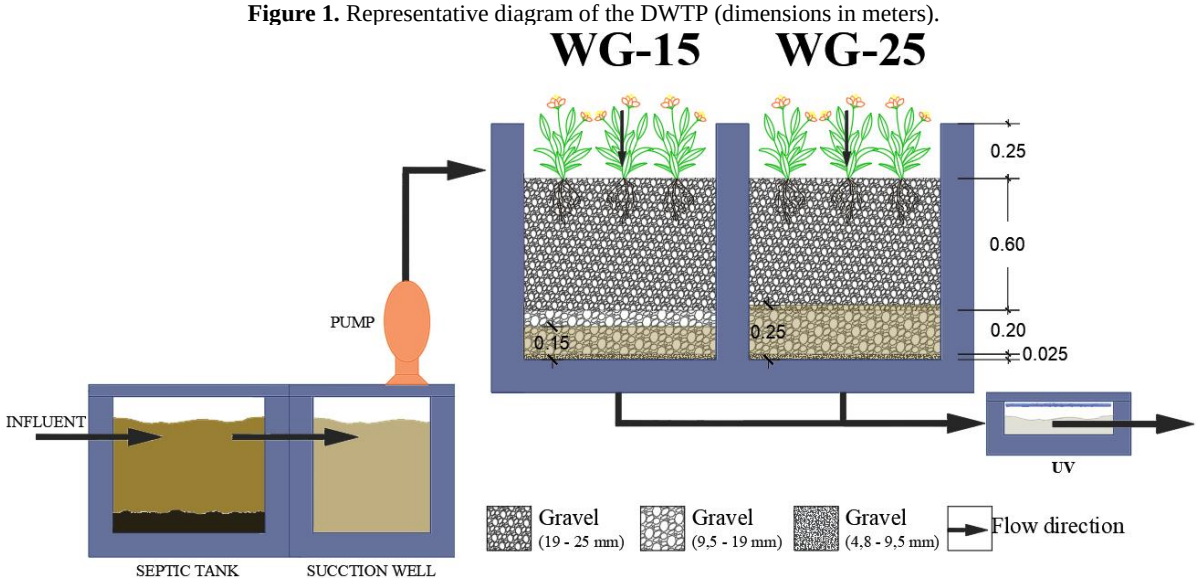
Thus, combining the technical solution of wastewater treatment with research, teaching, and extension, a full-scale decentralized wastewater treatment plant (DWTP) with four PS-VFCW units was built to treat domestic wastewater from student residences located on the UFSM Campus in Frederico Westphalen, Rio Grande do Sul, Brazil. This work aims to evaluate the performance of DWTP treatment at the beginning of its operation.

METHODOLOGY

The DWTP was designed to treat 7,200 L d^{-1} of domestic wastewater generated in the student residence. The system consists of a septic tank, suction well, pumping system, four PS-VFCW units (two containing gravel (dimensions between 9.5 e 19 mm) as the main support layer and two containing sand (effective diameter of 0.21 mm), a tank for ultraviolet disinfection, and a tank for storage/reuse. Each PS-VFCW has a surface area of 23.80 m² and are planted with *Canna x generalis*. The operation of the

DWTP began in September 2023, and this work focuses on the physical-chemical quality parameters of the effluent monitored for the two units with gravel-based support medium during the first four months of operation (Figure 1): pH, temperature, alkalinity, total suspended solids (TSS), nitrogen, and chemical oxygen demand (COD), following the guidelines outlined by APHA et al. (2017). The units were named WG-15 and WG-25 for better understanding: the "G" stands for gravel, and the subscript numbers indicate the saturation level, 0.15 m or 0.25 m.

Figure 1. Representative diagram of the DWTP (dimensions in meters).



RESULTS AND CONCLUSIONS

The results of the physicochemical analysis, and the box plots for pH, COD, TSS e NH_4^+-N are presented in Table 1 and Figure 2, respectively.

Table 1. Average physicochemical results and standard deviation of the sampling campaigns.

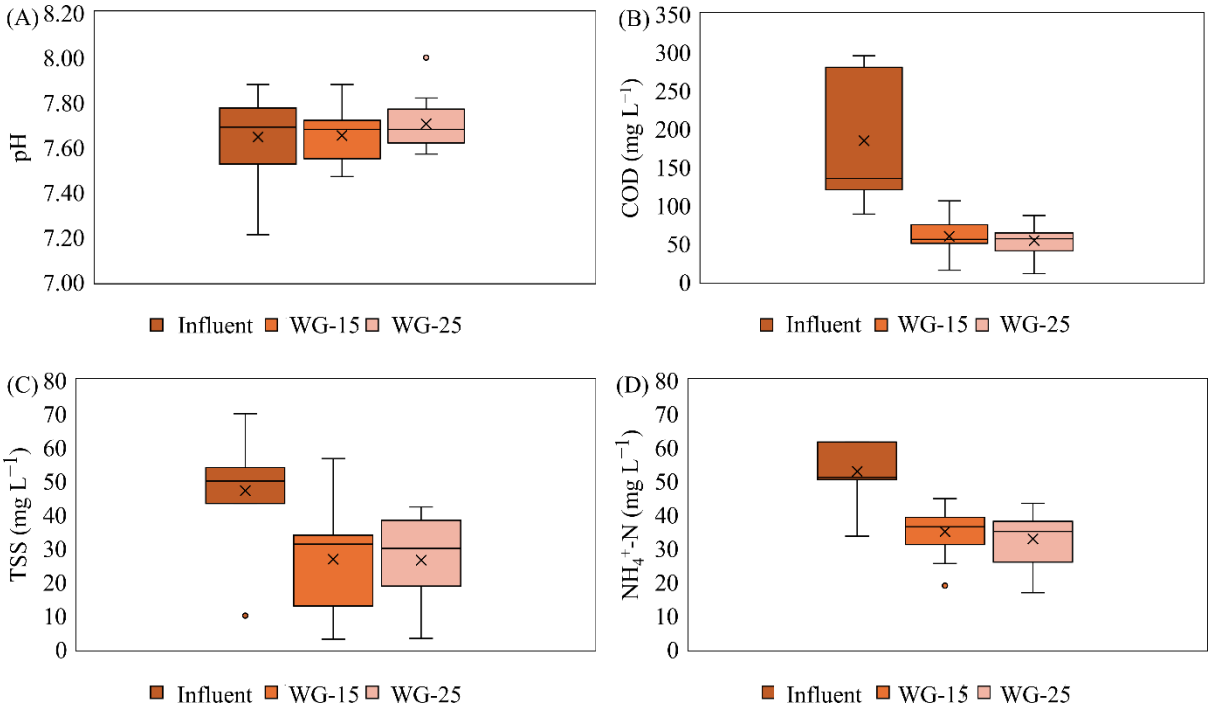
	Influent	WG-15		WG-25	
Parameter	Media ± SD	Media ± SD	Efic. (%)	Media ± SD	Efic. (%)
pH	7.6 ± 0.2	7.7 ± 0.1	-	7.7 ± 0.1	-
Temperature (°C)	22.1 ± 1.5	21.9 ± 1.4	-	21.9 ± 1.5	-
Alkalinity	280 ± 37	226 ± 52	-	224 ± 55	-
COD (mg L^{-1})	175 ± 76	60 ± 23	64	50 ± 20	69
TSS (mg L^{-1})	47 ± 22	27 ± 16	48	26 ± 13	47
NH_4^+—N (mg L^{-1})	60 ± 27	39 ± 16	34	36 ± 15	39

Note: Efic. (%) = removal efficiency; SD = standard deviation.

The system demonstrated very satisfactory operation, the specimens of *Canna x generalis* showed good overall apparent development. The removal efficiencies were satisfactory even at the beginning of the system's operation: 64% (WG-15) and 69% (WG-25) for COD; 34% (WG-15) and 39% (WG-25) for NH_4^+-N and 48% (WG-15) and 47% (WG-25) for TSS (Figures 1 and 2). Gravel-based CW systems fully acclimatized to domestic wastewater treatment, as reported in the literature, demonstrate efficiencies ranging from 43% to 75% for COD, 64% to 75% for NH_4^+-N, and 48% to 72% for TSS

(SHUKLA et al., 2022). Furthermore, it is worth mentioning the low load applied to the system, 9 g COD m^{-2} day^{-1}, below the recommended for Brazilian climatic conditions, which ranges from 20 to 40 g COD m^{-2} day^{-1}, equivalent to 10 to 20 g BOD m^{-2} day^{-1} (ABNT, 2024).

Figure 2. Box plots regarding the pH (A), COD (B), TSS (C), and NH_4^+-N (D) analyses from the thirteen sampling campaigns; box: 25%-75%; whisker: outlier range; line = median; x = mean.



This data, along with other researches and the system monitoring, can contribute for a better understanding of the technology and the efficiency of the system over time, especially the units with gravel as their main media support, which is a material that is readily available and economically interesting. As it is a real-scale system, the results obtained will serve as an example for future decision-making regarding the installation of other systems, as well as for the dissemination of PS-VFCW technology in rural and/or isolated communities, contributing to the improvement of the current scenario of basic sanitation and wastewater treatment.

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