Intensification of aeration to optimize nutrient removal in vertical-flow constructed wetlands

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Highlights:

· intensification of aeration increased removal of COD, TN, and TP in 12%, 37%, and 33%.

· autoclaved concrete (AC) used as support material materials buffered the alkalinity consumption.

· textural properties and composition of AC enhanced the performance of wetlands.

Keywords: construction waste; autoclaved cellular concrete; *Eichhornia crassipes*

INTRODUCTION

Constructed wetlands (CWs) can efficiently remove organic matter, nitrogen, phosphorus, heavy metals, and emerging contaminants through natural processes (Chen et al., 2021). CWs are recognized for their potential in the reliable treatment of various types of wastewater, as verified by Khan et al. (2022). However, Ilyas and Van Hullebusch (2020) demonstrated that some limitations have motivated the search for optimization of these systems through the use of hybrid models, promotion of effluent recirculation, intensification of artificial aeration, application of adsorbent materials and other configurations and operational conditions to enhance the treatment. Thus, the application of intermittent aeration was evaluated in this study in vertical subsurface constructed wetlands vegetated with *Eichornia crassipes* in construction waste for the synthetic effluent treatment.

METHODOLOGY

Two subsurface vertical flow constructed wetlands (CW-VF) set up in polypropylene containers (0.57 x 0.40 x 0.32 m; 56 L each), filled with autoclaved aerated concrete (AC). The macrophyte *Eichornia crassipes* (22 plants m^{-2}) were planted in the material layer (0.20 m from the surface) under a saturated bottom with 0.05 m height. The control wetland (CW-C) and the wetland operated under intermittent aeration (CW-A) were artificially aerated by an air compressor BOYU, model SC-7500, linked to a porous air curtain (BOYU) positioned at the bottom of the system to promote air diffusion (Fig.1).

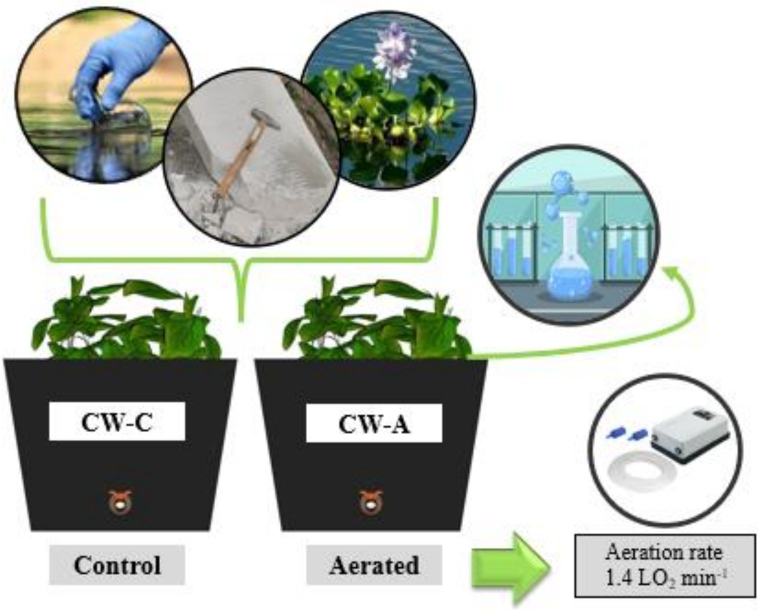

Fig.1 – Scheme of the subsurface vertical-flow constructed wetlands

The aeration flow rate of 1.4 LO_2 min^{-1} (8.77 mgO_2 L^{-1}) was controlled by a timer with 3 h/day of aeration followed by an intermittency of 7 h. The systems were fed with synthetic effluent composed of $C_{12}H_{20}O_{10}n$ (1.5 mg L^{-1}), $CaCl_2$ (4.5 mg L^{-1}), $C_6H_{10}O_5$ (5.7 mg L^{-1}), $MgCl_{26}H_2O$ (7.0 mg L^{-1}), $C_{12}H_{22}O_{11}$ (10.0 mg L^{-1}), KH_2PO_4 (13.2 mg L^{-1}), NH_4Cl (51.0 mg L^{-1}), $NaHCO_3$ (100 mg L^{-1}), NaCl (250 mg L^{-1}), wheat flour (100 mg L^{-1}) and beef extract powder (105.7 mg L^{-1}) at 48-48-72 h, resulting in COD from 174 to 219 mg L^{-1}, TN from 31 to 43 mg L^{-1}, and TP from 10 to 14 mg L^{-1}. Samples of the influent and effluent of the systems were characterized by determining the liquid temperature, pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP) in duplicate according to APHA (2017) after 24 h of treatment.

RESULTS AND CONCLUSIONS

Temperature varied in the influent samples from 19.8 to 22.6 ºC and in the effluent samples from 20.5 to 23.5 ºC for CW-C and 20.8 to 23.8 ºC for CW-A, resulting in values lower than 25-35 ºC indicated for denitrification by Sezerino et al. (2015). Higher pH values in the effluent samples of CW-C (8.5 - 8.6) and CW-A (7.7 - 8.0) than in the influent samples (7.1 - 7.3) are probably related to carbonates and hydroxyls of the support media (Cabral et al., 2021). These pH values favor nitrification and denitrification since a pH below 7.5 inhibits nitrification, and a pH above 8.5 promotes the intensification of ammonia volatilization (Vymazal, 2007). In addition, the physicochemical properties of AC could contribute to maintaining pH in the range of 7.5-8.0, reducing the addition of an external source of alkalinity since these materials buffer the alkalinity consumption.

The DO in the effluent varied from 0.2 to 1.3 mgO_2 L^{-1} for CW-C and 0.8 to 1.7 mgO_2 L^{-1} for CW-A, suggesting the predominance of anoxic conditions (< 2.0 mgO_2 L^{-1}) during the operation (Metcalf &

Eddy, 2016). During the feeding, air is introduced in the support material as the effluent drains, promoting a high transfer of oxygen to the micropores of the material and creating aerobic microenvironments (Brix & Schierup, 1990). For ORP, the values ranged from -145 to -64 mV in WC-C and -62 to +33 mV in WC-A in the effluent samples, i.e., anoxic (-100 to +100 mV) and slightly anaerobic (< +100 mV) conditions, respectively, following Matos et al. (2010).

The average COD, TN, and TP were 194, 37, and 12 mg L^{-1} in the influent samples during the operation of the systems, respectively. In the effluent samples, the average values for these parameters were 58, 26, and 4 mg L^{-1} for CW-C and 33, 12, and 1 mg L^{-1} for CW-A, respectively. CW-C and CW-A achieved average removal efficiencies of 71% and 83% for COD, 31% and 68% for TN, and 61% and 94% for TP, respectively (Fig. 2).

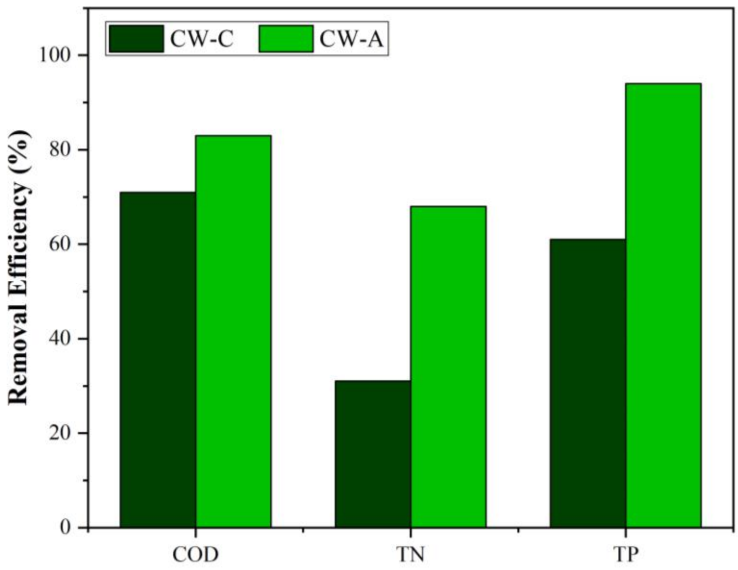

Fig. 2 – Removal efficiencies of COD, TN, and TP in CW-C and CW-A

Statistical analyses revealed significant differences between the systems (p-value < 0.05) with better performance for CW-A, indicating that the intensification of aeration by intermittent mode optimized the performance of the system in removing these parameters. In addition, the porous characteristics and composition (Ca, Al, Fe, and Si) of AC, along with the mechanisms of microbial transformation, absorption, assimilation by plants, precipitation, and adsorption, favored removing COD, TN, and TP from the synthetic effluent..

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