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Long-term evaluation of a constructed wetland for greywater treatment

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Highlights:

- After 20 years of operation, BOD (<3 mg/L), nitrogen (<6 mg/l) and phosphorus (<0.5 mg/l) were still efficiently removed.
- Decrease in phosphorus treatment efficiency indicated a decrease in adsorption capacity of Filtralite®P with time.

Keywords: biofilters; graywater; nature-based solutions (NBS)

INTRODUCTION

With the growing implementation of source-separating wastewater systems, there is potential scope for research on the decentralized collection and treatment of greywater (GW). GW accounts for more than 70% of the volume of domestic wastewater and yet contains significant amounts of organic matter, nutrients, pathogens, and chemical pollutants (Oteng-Peprah et al., 2018). Decentralized GW treatment can be economical and allow efficient heat recovery via heat exchangers and if treated locally, reduced energy demand for the transport of the greywater (Li et al., 2009; Larsen, 2015). Moreover, the treatment of GW and reuse could become a part of integrated water resource management and potentially contribute to the Water-Energy-Food NEXUS (Pahl-Wostl et al., 2018). Among various decentralized GW treatment systems, constructed wetlands are attractive as a nature-based solution, providing both physicochemical and biological treatment influenced by the substrate used, vegetation root system, biofilm growth, and atmospheric conditions (Boano et al., 2020). However, the number of studies on full-scale constructed wetlands treating real GW (i.e. not synthetic) is limited. In addition, long-term evaluation of a full-scale constructed wetland has not been carried out previously. Therefore, this study aims to investigate a constructed wetland that has been in operation for more than 20 years and assess its current GW treatment performance under the Scandinavian seasonal conditions as well as the treatment efficiency over time.

METHODOLOGY

The constructed wetland in Klosterenga, Olso was built in 2001 and received source-separated greywater from a residential building with approximately 100 residents. The greywater entered a septic tank with three chambers followed by vertical-flow aerobic biological filters (biofilter) and an anaerobic horizontal subsurface flow (HSSF) phosphorus filter (Figure 1). The biofilter was made of 10 fiberglass tanks and filled with 2–10 mm light-weight aggregate (LWA) Filtralite®. The total surface area and the depth of the biofilter was 72 m2 and 0.6 m, respectively. Greywater was pumped from the last septic tank chamber and distributed over the biofilter using high-pressure nozzles and the GW percolated through the filter under unsaturated conditions. Additionally, air pumps were installed for the aeration in the biofilter. The effluent from the aerobic biofilter then passed into the anaerobic HSSF filter (approx. dimension: 11.75 x 9.3 x 1.8 m) which mainly consisted of the phosphorus-sorbing filter material LWA Filtralite® P of size 0.5–4 mm(Figure 1). The retention time in the HSSF was approximately 7–8 days. The final effluent from the HSSF entered the outlet chamber before being discharged into the city's stormwater drainage system.

Five sampling campaigns were carried out between the years 2023-2024, i.e. in February, June, September, November, and January (2024), to include different seasonal conditions (i.e. colder or warmer). During each campaign, samples were taken on three consecutive days. The samples include influent greywater before entering the biological filters (after sedimentation in the septic tank) and the treated greywater after the wetland. Various quality parameters were analyzed of which biochemical oxygen demand (BOD), nutrients and *E. coli* are presented in this abstract. These parameters were compared with previously available data from the years 2001 – 2014 and with the discharge limit of Oslo city (i.e. 20 mg/l BOD and 1 mg/l total phosphorus (tot-P)).

RESULTS AND CONCLUSIONS

During the years 2023 and 2024, the BOD reduction exceeded 98%, with effluent concentrations ranging from 1.0 to 2.7 mg/l, which were lower than previously measured BOD concentrations (2003 – 2014) (Fig. 1). The effluent concentrations of tot-P during 2023 – 2024 were 0.15 – 0.45 mg/l (66 – 88% reduction) which was slightly higher than the concentrations measured in previous years (Fig. 1). Since the chemical sorption capacity is reduced over time, the increase of effluent tot-P is expected. The total nitrogen concentrations in the effluent were in the range of 3.0 – 5.6 mg/l (59 – 74% reduction) in the samples from 2023 – 2024 (Fig. 1). The results of indicator bacteria *E. coli* in samples from 2023 – 2024 showed <1 MPN/100 ml in the effluent and corresponded to 3.4 log reductions.

After more than 20 years since the beginning of its operation in 2001, the effluent quality indicates that the constructed wetland has performed efficiently, and it meets the discharge requirements of Oslo city as well as the EU regulation for greywater reuse in the agricultural sector or bathing water quality. The results from the different sampling campaigns during the years 2023-2024 show that seasonal changes (i.e. warmer or colder months) have a small influence the treatment efficiency. However, the efficiency in treating phosphorus has been reduced over the years due to reduced sorption capacity but the effluent concentrations were still below the discharge limit of 1 mg/l. Therefore, it can be concluded that the Klosterenga constructed wetland is a resilient, low-maintenance nature-based solution for effective long-term greywater treatment in urban environments and can provide aesthetical values.

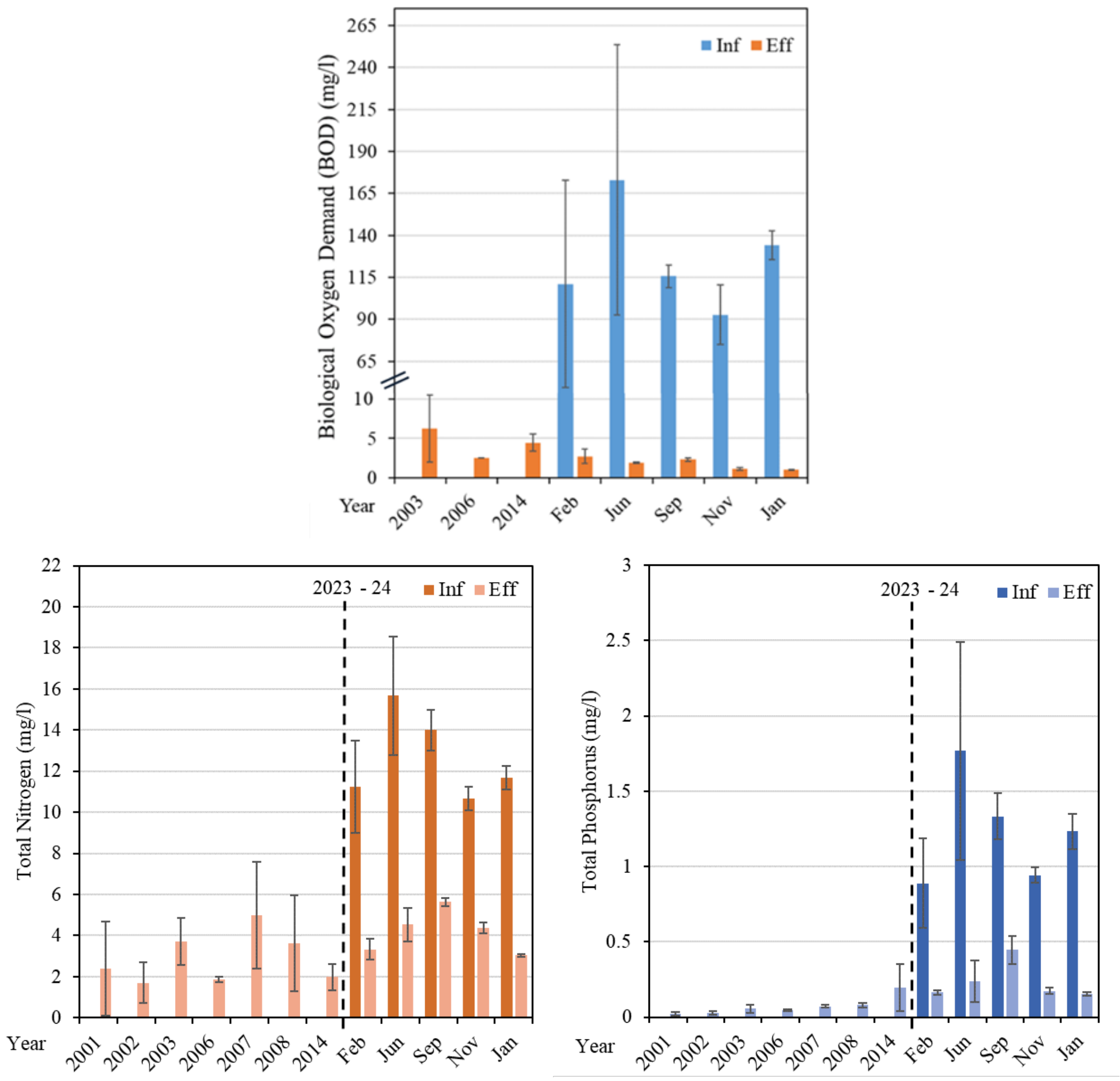

Figure 1: Mean influent (Inf) and effluent (Eff) concentrations of BOD, nitrogen and phosphorus from the Klosterenga constructed wetland from 2001 until January 2024. Influent concentrations until 2014 were not available. Standard deviations are shown as error bars.

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