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Exploring novel approaches for wetland conservation and wise use, water management, sustainable use and ecotourism, restoration of degraded or lost sites, pollution control and climate change

Program and Abstracts

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A2. Attenuation of Pharmaceutical Substances: Phytoremediation using Constructed Wetlands

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INTRODUCTION

Currently, wastewater treatment plants (WWTPs) do not efficiently remove pharmaceutical substances (PS). Thus, such substances are now frequently found in aquatic ecosystems worldwide. Also, concentrations of some PS in treated effluents exceed Environmental Quality Standards proposed by EU legislation. One resource-efficient option for increasing PS removal in WWTP effluents is to use constructed wetlands (CWs) as an attenuation step (Breitholtz et al. 2012; Li et al. 2014). However, very little research has been done on how to maximize the PS attenuation capacity of CWs. Therefore, a project with the aim to investigate **reduction of different pharmaceutical substances in CWs** with different vegetation compositions and water depths, was performed at the Experimental Wetland Area (EVA) located 20 km north of Halmstad, Sweden.

METHODS

EVA consists of 18 similar rectangular surface-flow CWs each 10 x 4 m^2 (surface area). Five pharmaceutical substances (diclofenac, carbamazepine, ibuprofen, sulfamethoxazole and naproxen) were spiked to nine CWs at concentrations typically found in secondarily treated wastewater. Three different types of CWs were used: A) unharvested wetlands with mixed vegetation and high mean water depth (0.55 m); B) similar to A) but with a low mean water depth (0.40 m); and C) harvested wetlands dominated by reed and high mean water depth (0.55 m). Samples for pharmaceutical concentrations were taken at the inlet and outlet of the CWs on day 0, 14, 21, 28, 42 and 56 after spiking. Also, oxygen, temperature and pH was measured. The hydraulic loading rate to the CWs was 120 mm day^{-1} (±14 mm day^{-1}) throughout the study period (Aug-Oct 2015).

RESULTS and DISCUSSION

Results show that the relative reduction (% reduction of total loaded PS mass) was highest for ibuprofen (>94 %) followed by diclofenac (85-88 %) and sulfamethoxazole (54-66%). Both carbamazepine and naproxen had relative reductions below 37 % (Fig. 1). No significant difference were found between the treatments.

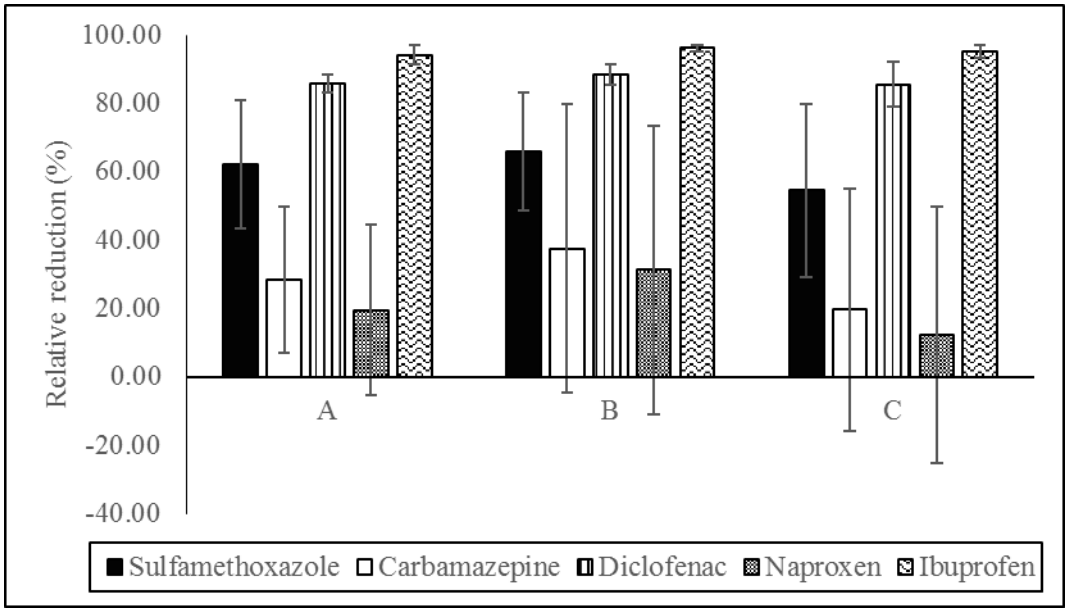

Fig. 1. Relative reduction (as % reduction of total loaded mass) of five pharmaceutical substances in the surface-flow constructed wetlands (CWs) consisting of: A) unharvested CWs with mixed vegetation and high mean water depth (0.55 m); B) similar to A) but with low mean water depth (0.40 m); and C) harvested CWs dominated by reed and high mean water depth (0.55 m). Error bars show standard deviation. n = 3.

The present study found higher relative reductions for ibuprofen, diclofenac and sulfamethoxazole compared to those reported by Verlicchi and Zambello (2014) (Table 1). Also, the reduction of naproxen and carbamazepine was within the rates reported by the cited study. Berglund et al (2014) conducted an experiment in EVA using sulfamethoxazol (spiking concentration 1 µg/L) and found a 77 % relative reduction, which is very close to the rates reported in the present study (Table 1). Matamoros and Salvadó (2012) reported similar mass reduction as the ones found in the present study for ibuprofen (92%), carbamazepine (43%) and diclofenac (93%) for a polishing tertiary wastewater treatment system consisting of a pond and surface flow CW. Recently, Nuel et al. (2018) reported that the reduction efficiency of PS was higher in warmer seasons compared to colder ones. The study at EVA was conducted during 25 August-19 October, and thus, the reduction could be very different if the study was conducted in peak summer or a cold winter period.

Table 1. Substances used in the present research project, their substance class, typical relative reductions in surface flow constructed wetlands receiving secondary treated wastewater (Verlicchi and Zambello 2014) and reductions reported in the present study (bold italic).

Substance	Substance class	Relative reduction (%)
Sulfamethoxazole	Antibiotic	16-24 (***54-66***)
Carbamazepine	Anti-epileptic	12-90 (***20-37***)
Diclofenac	Anti-inflammatory	8-79 (***85-88***)
Naproxen	Beta-blocker	14-52 (***12-31***)
Ibuprofen	Anti-inflammatory	48-76 (***94-96***)

Despite keeping a somewhat constant HLR to the CWs during the study period, the area-specific mass reduction of ibuprofen and diclofenac, respectively, increased with mass load (Fig. 2). In contrast, area-specific mass load of carbamazepine and naproxen, respectively, led to a decrease in area-specific mass reduction of these substances.

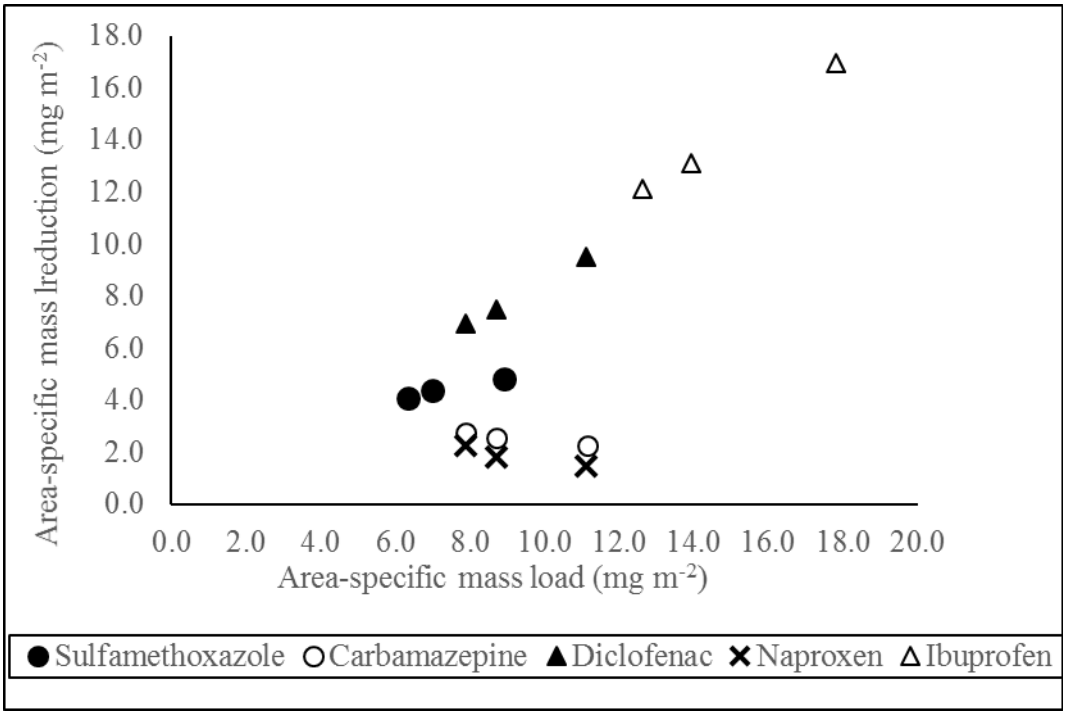

Fig. 2. Area-specific mass reduction as a function of mass load during the whole study period of five pharmaceutical substances in the surface flow constructed wetland system EVA. *n* = 3.

Area-specific mass reduction of sulfamethoxazole reached a plateau at around a mass load of 9 mg m^{-2} (Fig. 2). Currently, published literature seldom reports PS reduction in CWs using the unit *area-specific mass reduction.* A more regular use of this parameter is proposed when reporting PS reduction in CWs. This would make comparisons between different CW systems regarding their capacity to reduce PS much more relevant.

CONCLUSIONS

Relative reductions of PS achieved in the present study suggests that surface flow CWs could aid in reducing concentrations of these substance at levels typically present in secondary treated wastewater. Still, additional studies are needed to evaluate the long-term and seasonal behavior of PS reduction on CWs. Also, future studies should report reduction as area-specific mass removal to be able to make relevant comparisons between different CW systems regarding their capacity to reduce PS.

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