

Quantification of removal mechanisms in vertical-flow constructed wetlands as nature-based solutions for treatment of wastewater effluent

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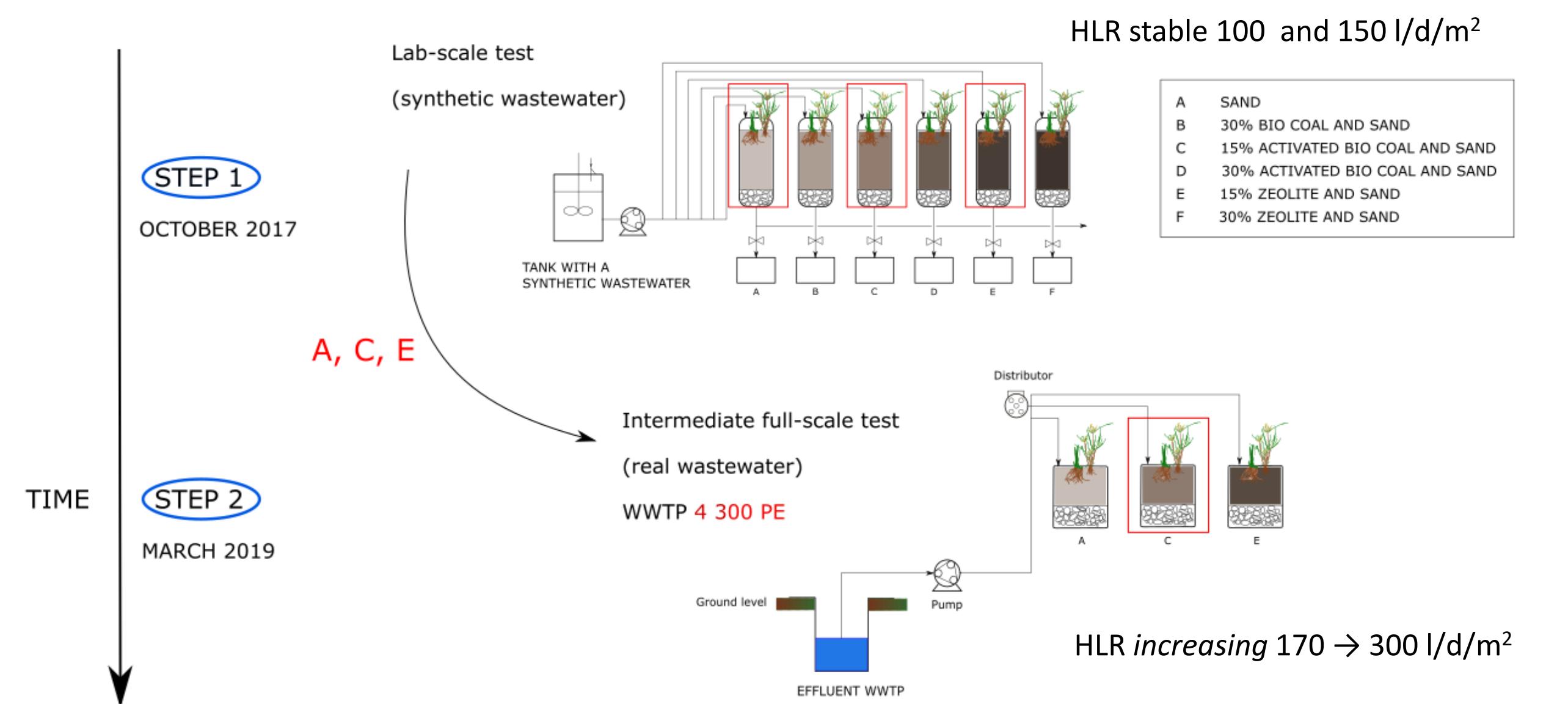
INTRODUCTION

Contamination by so-called micropollutant compounds – e.g. pesticides, herbicides and pharmaceuticals – has received increasing attention in recent years, as conventional WWTPs are not designed to remove micropollutants and presence of these compounds may constitute a potential risk for aquatic and terrestrial ecosystems. For this purpose, constructed wetlands are chosen, as they are low-cost in construction, operation and maintenance and therefore are potential candidates for suitable polishing of wastewater effluents.

In this project (EmiSûre, Interreg VA Greater Region), constructed wetlands have been used as tertiary treatment for micropollutants removal in small- to medium-sized WWTPs at the example of the Sure-catchment in Luxembourg and Germany (i.e. less than 100 000 PE). Satisfying results led to development of an aim to quantify the mechanisms contributing on the removal of micropollutants. These mechanisms are: 1. adsorption on selected substrates, 2. phytoremediation by selected plants and 3. microbial elimination by present fungi and bacteria. A methodology has been developed to quantify the contribution of each elimination mechanism minimizing the cross effect of the other. For determination of the adsorption potential of selected substrates, an adsorption on packed-bed columns is being carried out. Adsorption on columns is commonly used technology for polishing of wastewater effluents, therefore data coming from a pilot scale could be useful for possible further upscaling. Moreover, the results will offer comparison with the results of constructed wetlands in lab scale (lysimeters). Adsorption kinetics tests were carried out for completed description of this process. To evaluate the potential of selected plants to uptake micropollutants, phytoremediation experiments in hydroponic conditions were carried out. For evaluation and consequent comparison of plants' potential for micropollutants' uptake, fresh plants which did not treat any wastewater and plants taken from a constructed wetland used previously for treatment of wastewater effluent are investigated. Experiments for determination of elimination potential of fungi and bacteria are currently being designed.

METHODS

Initial part of a PhD research: Constructed wetlands



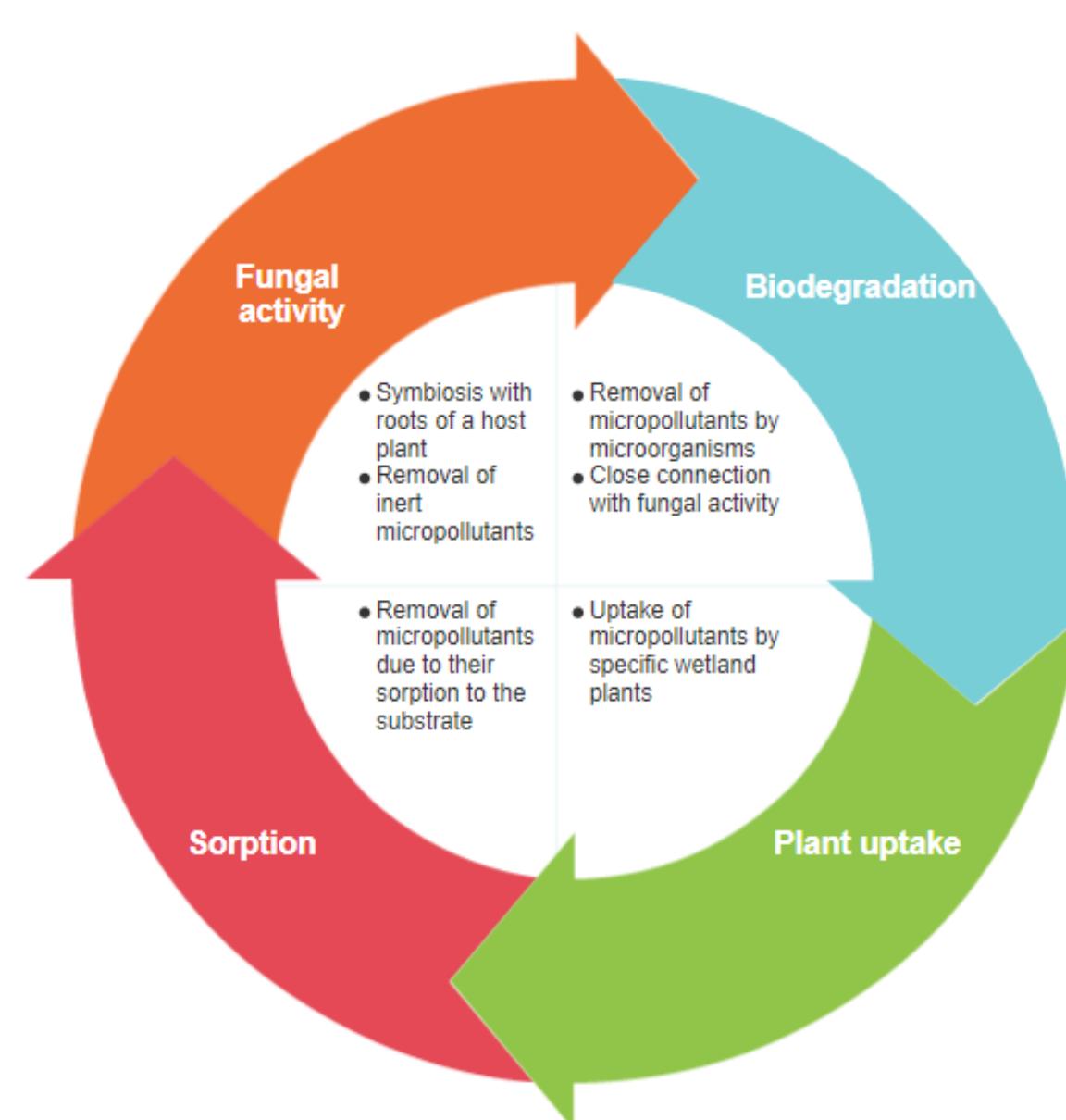
It was proved, that vertical-flow constructed wetlands are efficient in removal of selected micropollutants (MP). Therefore, following steps in terms of quantification of removal mechanisms are established:

- Evaluation of adsorption capacity of studied substrates A, C, E as the ones showing optimal results in terms of MP removal;
- Evaluation of the potential of selected plants for phytoremediation of selected MP;
- Evaluation of microbial activity of the used fungi and bacteria in terms of removal of selected MP.

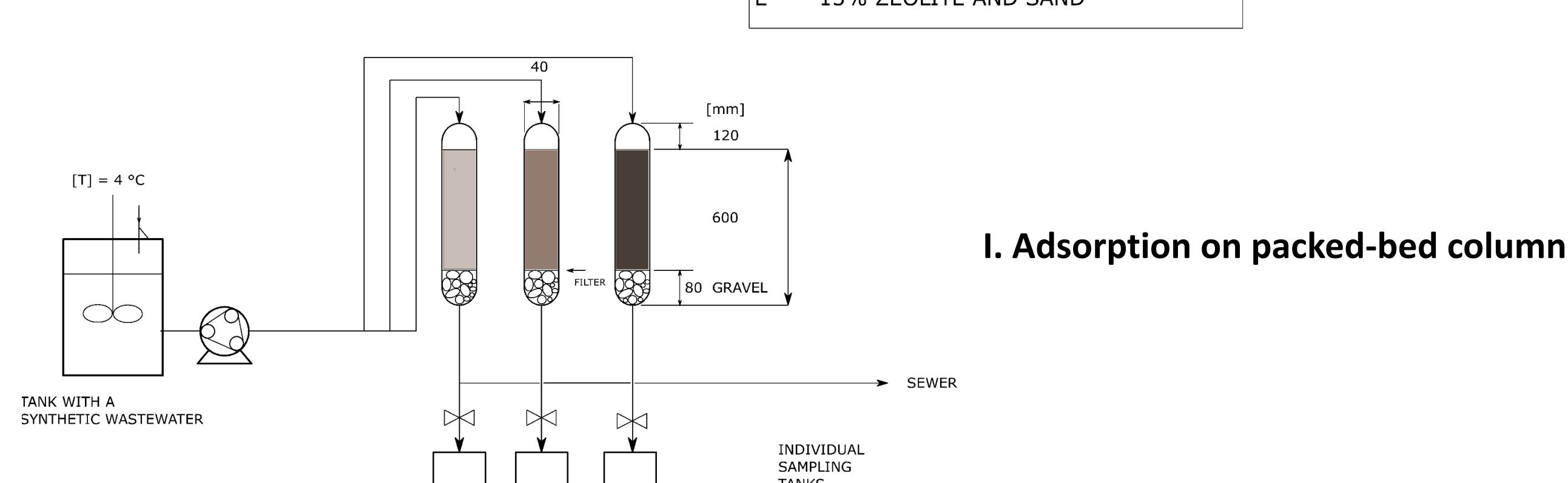
Main part of a PhD research: Quantification of mechanisms of constructed wetlands contributing on removal of micropollutants from wastewater

"Splitting" of the removal mechanisms present in constructed wetlands:

- ✓ **Adsorption:** adsorption on packed-bed columns and adsorption kinetics;
- ✓ **Phytoremediation:** experiments with selected plants (*Phragmites australis*, *Iris pseudacorus*, *Lythrum salicaria*) used in constructed wetlands and fresh ones;
- **Microbial activity:** currently designed.



A - SAND
C - 15% ACTIVATED BIO COAL AND SAND
E - 15% ZEOLITE AND SAND



II. Phytoremediation by selected plants

- A - *Phragmites australis* "fresh";
- B - *Iris pseudacorus* "fresh";
- C - *Lythrum salicaria* "fresh";
- D - *Phragmites australis* "adapted" – from CW Reisdorf;
- E - *Iris pseudacorus* "adapted" – from CW Reisdorf.



RESULTS & DISCUSSION

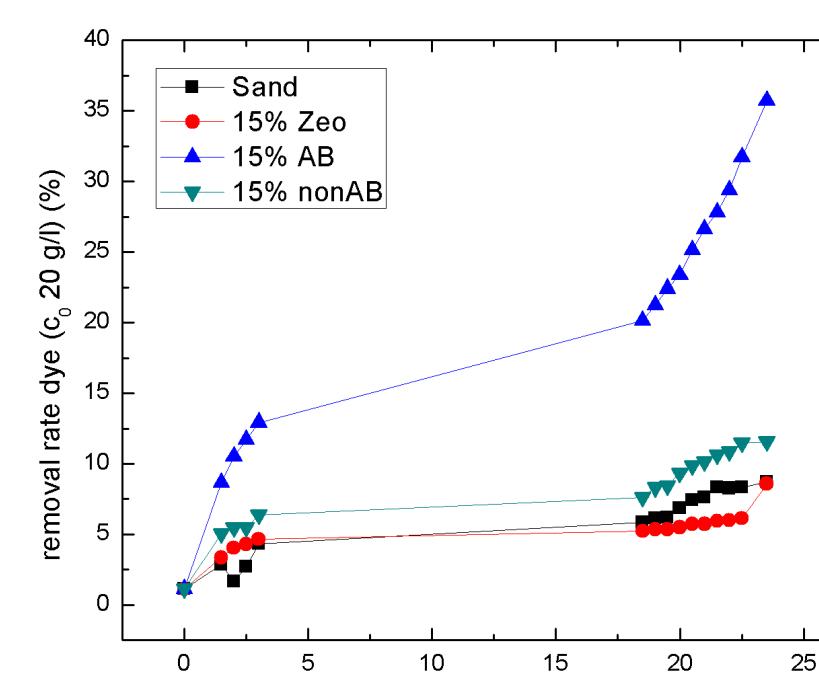
Constructed wetlands

In Step 1, removal of 22 out of 27 compounds was successful with more than 90 % efficiency. In Step 2, some micropollutants were removed with the same efficiency, as in case of lysimeters – Step 1 (AMPA, Benzotriazole), some micropollutants were better removed under increased HLR (Carbamazepine, DEET).

Removal mechanisms

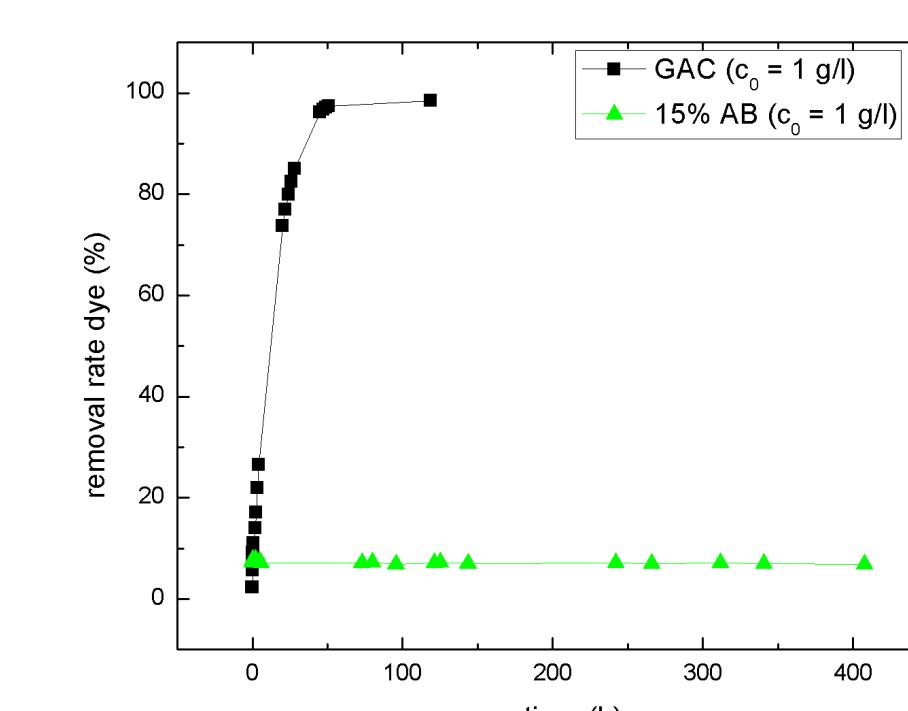
Adsorption

- ✓ Results from kinetics showed, that the substrates have a low adsorption capacity in comparison to conventionally used substrates, e.g. Granulated Activated Carbon (GAC);



← Adsorption on EmiSûre substrates, $c_0 = 20 \text{ g/l}$.

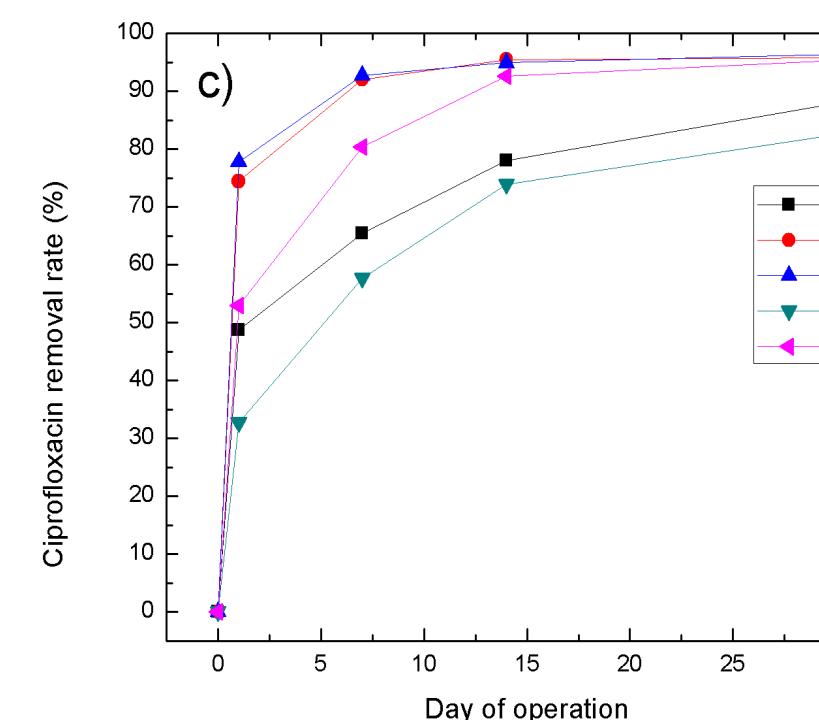
Comparison of adsorption capacity of GAC and substrate with the highest adsorption capacity (C), $c_0 = 1 \text{ g/l}$.



- ✓ Results from adsorption columns are to be analyzed in near future.

Phytoremediation

- ✓ 25 out of 27 micropollutants were removed with more than 20 % in case of *Lythrum salicaria*;
- ✓ As an independent process, phytoremediation is relevant polishing technology for wastewater effluents in cases of e.g. fluorosurfactants (removal rate up to 30 %), beta-blockers (removal rate up to 50 %) and antibiotics, example of ciprofloxacin (removal rate up to 90 %).



← Removal of ciprofloxacin by selected plants.

CONCLUSIONS

Constructed wetlands

- ✓ Optimal substrate with selected configuration was found out for the efficient removal of micropollutants from wastewater effluent;
- ✓ It was proved, that constructed wetlands in vertical sub-surface flow are sufficient technology for elimination of micropollutants from wastewater effluent from small and medium-sized WWTPs.

Removal mechanisms

- ✓ Adsorption efficiency of the studied substrates does not seem to be that high, as in case of conventionally used adsorbents. However, overall removals by adsorption will be known after delivery of the results from adsorption columns;
- ✓ Results show, that phytoremediation seems to be relevant mechanism contributing on the removal of micropollutants and that choice of selected plants improves overall removal efficiency while implemented in constructed wetland;
- Experiments for establishment of the microbial activity are to be carried out. It is supposed, that presence of specific bacteria and fungi will increase the uptake ability of selected plants.

References

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