



Improving the efficiency of wastewater treatment plants: Bio-removal of heavy-metals and pharmaceuticals by *Azolla filiculoides* and *Lemna minuta*

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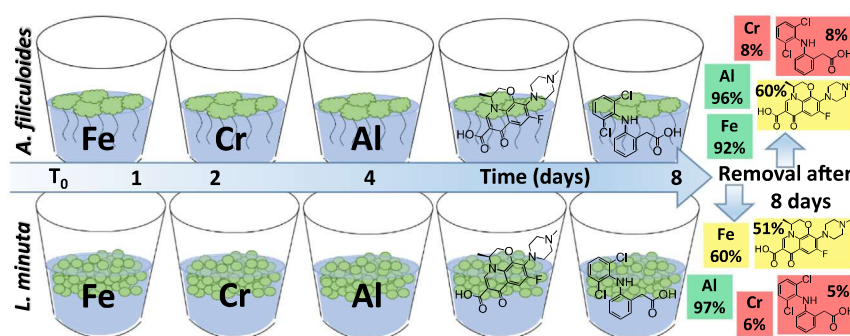
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HIGHLIGHTS

- *A. filiculoides* did not show any symptoms of toxicity for all treatments.
- *L. minuta* showed impaired growth in the presence of Fe, Cr and diclofenac.
- *A. filiculoides* and *L. minuta* showed a Fe removal of 92% and 60%.
- Both plant species showed Al removal >95% in the solutions.
- *A. filiculoides* and *L. minuta* showed a levofloxacin removal of 60% and 51%.

GRAPHICAL ABSTRACT



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ABSTRACT

In this study, we investigated the removal of Fe(III), Cr(VI), Al(III), diclofenac, and levofloxacin from treated wastewater in the presence of the free-floating plants *Azolla filiculoides* and *Lemna minuta*, to understand whether these species can be effectively used in a surface flow constructed wetland as wastewater refining treatment. Fe and Al were selected owing to their wide use as coagulant agents in wastewater treatment plants for promoting clariflocculation processes, whilst Cr was chosen due to its common use in industry. Diclofenac and levofloxacin, two molecules belonging to the most widely used pharmaceutical classes in the world, were studied as representative anti-inflammatory drugs and antibiotics, respectively. The study was performed at laboratory scale, exposing the plants separately to each individual contaminant at the concentrations of 5 mg L^{-1} for the metals (i.e. 2.5–5 times higher than the European limits concerning discharge into surface water), and $1 \mu\text{g L}^{-1}$ for the pharmaceuticals (concentration levels commonly found in wastewater). Depending on the plant species and contaminant tested, the range of different effects observed included low toxicity (i.e. Cr, Fe and diclofenac in *L. minuta*) and even a stimulatory effect on plant growth (i.e. for *A. filiculoides* with Al and for *L. minuta* with Al and levofloxacin). Moreover, both species proved to be very effective in the removal of Fe, Al and levofloxacin, with *A. filiculoides* showing the best performance (removal efficiency of 92%, 96%, and 60%, respectively), whereas for Cr and diclofenac the removal was always less than 10%. The higher removal capacity of *A. filiculoides* compared to *L.*

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