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RESEARCH ARTICLE

Closing the loop in a constructed wetland for the improvement of metal removal: the use of *Phragmites australis* biomass harvested from the system as biosorbent

Elisabetta Bianchi[1] · Andrea Coppi[1] · Simone Nucci[1] · Alexandra Antal[2] · Chiara Berardi[2] · Ester Coppini[2] · Donatella Fibbi[2] · Massimo Del Bubba[3] · Cristina Gonnelli[1] · Ilaria Colzi[1]

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Abstract

Among the numerous clean-up techniques for water treatment, sorption methods are widely used for the removal of trace metals. *Phragmites australis* is a macrophyte commonly used in constructed wetlands for water purification, and in the last decades, its use as biosorbent has attracted increasing attention. In view of a circularly economy approach, this study investigated improvement of trace metal removal by recycling the biomass of *P. australis* colonizing a constructed wetland, which operates as post-treatment of effluent wastewater from an activated sludge plant serving the textile industrial district of Prato (Italy). After the annual mowing of the reed plants, the biomass was dried and blended to derive a sustainable and eco-friendly biosorbent and its sorption capacity for Fe, Cu, and Zn was investigated comparing the batch system with the easier-to-handle column technique. The possibility of regeneration and reuse of the biosorbent was also evaluated. The biomaterial showed an interesting sorption capacity for Cu, Fe, and Zn, both in batch and in column experiments, especially for Fe ions. The immobilization of the biosorbent in column filters induced some improvement in the removal efficiency, and, in addition, this operation mode has the advantage of being much more suitable for practical applications than the batch process.

Keywords Biosorption · Circular economy · Columns · Trace metal removal · Plant dead biomass

Introduction

In this century, water pollution is of increasing concern to society, in addition exacerbated by the problem of water availability as a result of climate changes. Therefore, preventing the sources of water pollution further reaching the water bodies and cleaning the already polluted wastewaters are equally acquiring compulsory importance (Newete and Byrne 2016).

Trace metals represent the most common pollutants of high concern, since they cannot be biodegraded and can therefore accumulate in waters and soils (Ali et al. 2013). Into aquatic bodies, metals are mainly released from anthropogenic sources, even though in particular environments, their natural origin can be significant (Schwarzenbach et al. 2006). Excessive levels of such elements can cause serious toxic effects at any level of the ecosystem, including several health problems (Ali et al. 2013; Rahman and Singh 2019).

Conventional physical and/or chemical methods for the treatment of wastewater are expensive and not eco-friendly (Sharma et al. 2014); therefore, in the last decades, several methodologies have been developed for cleaning water. Among them, constructed wetlands (CWs) are effective systems based on the use of macrophytes that exploit their high growth rate and large root apparatus for the direct uptake of pollutants (Fibbi et al. 2012; Mitsch 2012; Newete and Byrne 2016) and, above all, for the synergistic interactions with the microbial communities of CWs (Sacco et al. 2006; Truu et al. 2009). Such simple and low-cost technology is extensively used for the treatment of domestic sewage, as well as of industrial and agricultural wastewater (Gorgoglione and Torretta 2018; Masi et al. 2018). In fact, CWs can efficiently

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✉ Ilaria Colzi
ilaria.colzi@unifi.it

[1] Department of Biology, Università degli Studi di Firenze, via Micheli 1, 50121 Florence, Italy

[2] GIDA S.p.A., via di Baciacavallo, 36, 59100 Prato, Italy

[3] Department of Chemistry, Università degli Studi di Firenze, Via della Lastruccia 3, 50019 Sesto Fiorentino, Florence, Italy