Journal of Environmental Management 147 (2015) 108–123

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Selection of wild macrophytes for use in constructed wetlands for phytoremediation of contaminant mixtures

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ARTICLE INFO

Article history:
Received 26 March 2014
Received in revised form
28 August 2014
Accepted 8 September 2014
Available online 28 September 2014

Keywords:
Industrial effluents
Native macrophytes
Constructed wetlands
Carex cuprina
Iris pseudacorus
Selection criteria

ABSTRACT

Constructed wetlands (CWs) offer an alternative to traditional industrial wastewater treatment systems that has been proved to be efficient, cost-effective and environmentally friendly. Most of the time, CWs are planted with proliferative species such as *Phragmites australis* or with plants originating from nurseries, both representing a risk for the natural biodiversity conservation of aquatic ecosystems located downstream of the CWs. For the removal of metals and organic pollutant mixtures present in industrial effluents, it is necessary to select tolerant plant species that are able to produce a high aboveground biomass and to develop a healthy belowground system. Wild plant species growing in aquatic bodies at industrial outfalls could constitute suitable tolerant species to use in CWs for industrial effluent treatment. To test this hypothesis, we assessed, under laboratory conditions (using an experimental design), the tolerance to mixtures of metals (Al, As, Cd, Cu, Cr, Fe, Mn, Ni, Pb, Sn, Zn) or/and organic pollutants (THC, PHE, PYR, LAS) of five European sub-cosmopolitan native macrophytes (*Alisma lanceolatum*, *Carex cuprina*, *Epilobium hirsutum*, *Iris pseudacorus* and *Juncus inflexus*) that had been collected in a polluted Mediterranean wetland, after a field study (crossing ecological relevés and analyses of contaminant concentrations in water and sediments). Our results demonstrated that research on phytoremediation of industrial effluents should focus much more on the use of native macrophytes growing at short distances from industrial discharges (such as *C. cuprina* in this study), and that root/shoot ratio, aerial height and proportion of green leaves are good and cost-effective indicators of plant tolerance to metals and organic pollutant mixtures in laboratory studies.

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1. Introduction

One of the burning issues in our industrial societies is the high consumption of water and the high demand for cleaning water (Schröder et al., 2007). Constructed wetlands (CWs) planted with macrophytes have proved their efficiency in treating a wide range of water pollution and are more and more widely used in European member states to treat several types of wastewater including industrial effluents (Hadad et al., 2006; Kadlec and Zmarthie, 2010; Khan et al., 2009; Vymazal, 2009). Most of the time, CWs are planted with resistant and proliferative species such as *Phragmites australis* or *Typha* spp. (Kadlec and Wallace, 2009; Vymazal, 2013). The use of such species in CWs may lead to the displacement of native vegetation in natural wetlands or disrupt the natural cycles of vegetation replacement that occur in native plant communities (Amon et al., 2007; Tulbure et al., 2007). Moreover, it has been

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http://dx.doi.org/10.1016/j.jenvman.2014.09.009
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recently proved that the large-scale replacement of wild plants by cultivars or hybrids of the same species represents a risk in the long-term, when implementing restoration activities, and is undesirable with regard to the conservation of native plants' biodiversity (Schröder and Prasse, 2013). It is therefore necessary to provide solutions for reconciling the objectives of pollution treatment in CWs and natural biodiversity conservation (Hsu et al., 2011).

When an area becomes moderately polluted, it is to be expected that tolerant species may replace those that have been lost (Grant, 2010). Therefore, macrophyte species that are growing in receiving bodies of water nearby effluent discharges may be tolerant to the contaminants persisting in the released effluents and are likely to constitute suitable native species to use in CWs for the treatment of these contaminants (Pilon-Smits, 2005; Ranieri and Young, 2012; Ranieri and Gikas, 2014; US EPA, 2000). Studies are needed to determine the pollution tolerance of wild macrophytes growing in contaminated water bodies and that are less competitive than the commonly used reeds and cattails.

Despite the significant progress that has been made in recent decades regarding the treatment of industrial effluents, good chemical and ecological status of water bodies located downstream of industrialized catchments are still difficult to achieve (Stalter et al., 2013). Additional retention and treatment systems such as CWs are necessary to reduce the ecotoxicity of industrial effluents and to preserve aquatic biodiversity and its ecological functions (Guittonny-Philippe et al., 2014; Schröder et al., 2007). Industrial wastewaters are characterized as complex mixtures with varying pollutants present with a wide range of concentrations (Soupilas et al., 2008). It is well known that in CWs, the growth of macrophytes and their depurative performance may be influenced by interactions among mixed pollutants (Zhang et al., 2011b). However, a limited number of data on wild macrophyte tolerance to mixtures of pollutants is available in the literature.

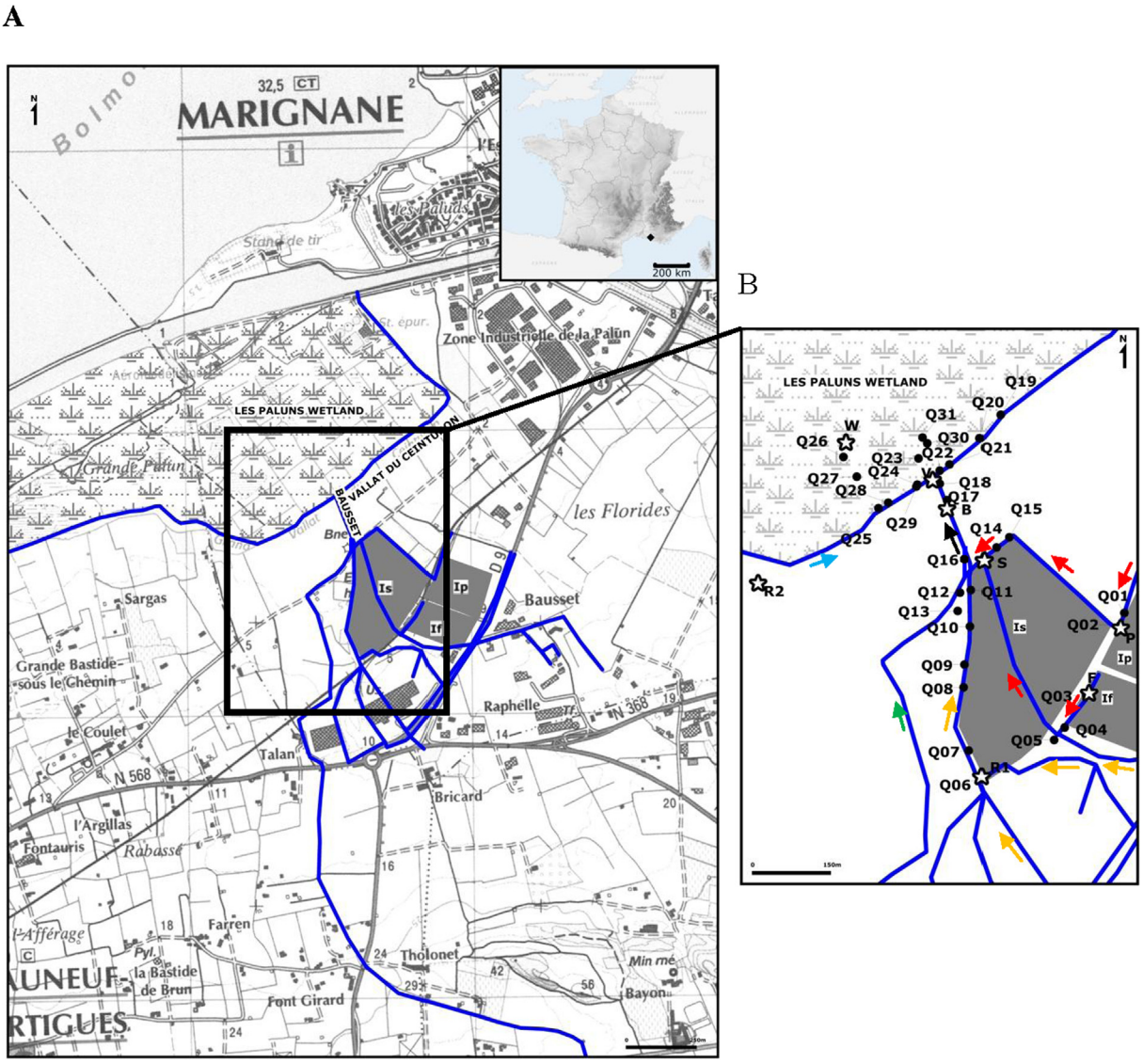

Fig. 1. (A) Localization of the study site (Marignane, South-Eastern France), interface zone between a protected wetland (Les Paluns) and an industrial zone (of which three main industrial areas, I_S, I_P and I_F, are represented in gray). Temporary streams and ditches are represented with blue lines. (B) Localization of the plots for plant ecological relevés (31 black dots: Q01 to Q31) and localization of the water and/or sediment sampling points (8 white stars: P, F, S, B, V, R1, R2, W). The direction of water flow is indicated with arrows. The color of arrows indicates the main water origin (green: catchment; orange: road-runoffs; red: industry discharges; dark: confluence; blue: wetland). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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