Science of the Total Environment 631–632 (2018) 252–261

Contents lists available at ScienceDirect

Science of the Total Environment

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

Translocation, accumulation and bioindication of trace elements in wetland plants

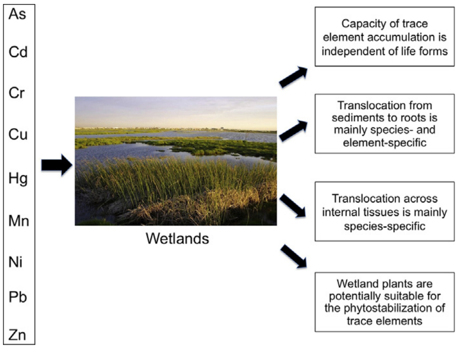
Giuseppe Bonanno [a,*], Jan Vymazal [b], Giuseppe Luigi Cirelli [c]

[a] Department of Biological, Geological and Environmental Sciences, University of Catania, Via Longo 19, 95125 Catania, Italy
[b] Czech University of Life Sciences Prague, Faculty of Environmental Sciences, Kamýcká 129, 165 21 Praha 6, Czech Republic
[c] Department of Agriculture, Nutrition and Environment, University of Catania, Via Santa Sofia 100, 95123 Catania, Italy

HIGHLIGHTS

- Capacity of trace element accumulation is independent of plant life forms.
- Translocation from sediment to roots is mainly species- and element-specific.
- Translocation across internal tissues is mainly species-specific.
- Wetland plants are potentially suitable for the phytostabilization of trace elements.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 11 December 2017
Received in revised form 4 March 2018
Accepted 4 March 2018
Available online xxxx

Editor: Charlotte Poschenrieder

Keywords:
Environmental pollution
Macrophytes
Trace elements
Element mobility
Phytoremediation
Bioindicators

ABSTRACT

This study aimed to shed further light on the capacity of macrophytes to translocate, accumulate and bioindicate the levels of trace elements present in contaminated water and sediments. Specifically, this study aimed to find evidence whether translocation, accumulation and bioindication are dependent on the kind of trace element and plant species. To investigate the correlation between trace elements in plants and in the environment, the concentrations of As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, and Zn were analyzed in twenty different wetland plants, and in water and sediments from a wetland area affected by urban and industrial pollutants. Results showed that wetland plants share some common characteristics such as high tolerance to toxic element levels, capacity of phytostabilization and different element concentrations in the various organs. Moreover, element translocation from sediments to roots seems more influenced by the kind of plant species and trace element, whereas translocation across the various organs seems mainly species-specific. No clear patterns of trace element translocation were identified according to plant life forms.

© 2018 Elsevier B.V. All rights reserved.

1. Introduction

Plant species play an important function in wetland geochemistry because they are the main living collectors and transporters of trace elements through active and passive absorption (Bose et al., 2008; Vodyanitskii and Shoba, 2015). Wetland plants can accumulate high levels of trace elements from water and sediments thanks to their well-developed root system, tolerance to toxicity, highly productive biomass, and stationary nature (Milošković et al., 2013; Rezania et al., 2016). In particular, wetlands are vulnerable to trace element inputs, and the impact of element pollution is of great concern for the

---

[*] Corresponding author.
E-mail address: bonanno.giuseppe@unict.it (G. Bonanno).

https://doi.org/10.1016/j.scitotenv.2018.03.039
0048-9697/© 2018 Elsevier B.V. All rights reserved.

ecosystem services affected (Mitsch and Gosselink, 2007; Bonanno, 2014; Bonanno and Vymazal, 2017). The consequences of high levels of trace elements in wetlands are also difficult to investigate for the complex behavior and interactions of such elements in aquatic ecosystems (Verhoeven et al., 2006). Trace elements may affect the fragile ecological stability of wetlands, whose fundamental role in nutrient cycling and pollution control is widely recognized (Everard, 2017). Investigating the relationship between trace elements in water/sediments and plant species is thus of the utmost importance to shed more light on those processes of element translocation at the interface of plant organisms and abiotic components.

Chemical contamination of water and soil resources is an ever-increasing issue in most ecosystems around the world (Szyczewski et al., 2009; Charlesworth et al., 2011; Bonanno and Orlando-Bonaca, 2018). Trace element contamination can be due to both natural geochemical processes (e.g., weathering of ultramafic rocks), and human activities (e.g., mining, smelting, combustion of fossil fuels, utilization of fertilizers and pesticides, etc.) (Kabata-Pendias and Mukherjee, 2007; Dhote and Dixit, 2009; Bonanno and Pavone, 2015). Because of their accumulative and non-biodegradable nature, trace elements are potentially hazardous to natural ecosystems, and thus to all living organisms (Tchounwou et al., 2012). High levels of trace elements may inhibit life processes, and are particularly dangerous in aquatic ecosystems where, once accumulated in sediments, they begin to move up the food web, and biomagnify at higher trophic levels, ultimately determining several chronic disorders in humans and animals (Gall et al., 2015). Some elements, however, act as important micronutrients for plants (e.g. Cu, Mn, Zn), even though such elements may have also toxic effects at higher concentrations (Babula et al., 2008; Kabata-Pendias, 2011). In turn, other elements (e.g., As, Cd, Cr, Hg, and Pb), have no known biological roles and can prove highly toxic to organisms even at low concentrations (Nagajyoti et al., 2010).

This study aimed to shed further light on the capacity of wetland plants to translocate, accumulate and bioindicate trace elements in water and sediments under toxic conditions in the field. To investigate the relationship between trace elements in plants and surrounding environment, the concentrations of As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, and Zn were analyzed in twenty different plant species growing in a wetland area affected by urban and industrial polluting inputs. These elements include fundamental micronutrients (e.g. Cu, Zn) and toxic elements according to the Italian Decree 260/2010. To date, relatively few studies have investigated the translocation processes of trace elements in large plant communities (e.g. Teuchies et al., 2013). The capacity of element uptake varies indeed among plants (Bothe and Słomka, 2017), and conducting a comparative analysis among several different species can contribute to better understand the dynamics of trace element mobility in wetland ecosystems. This study, in particular, aimed to identify common patterns of trace element translocation, but also to find further evidence that translocation and bioindication of trace elements are mainly species- and element-specific processes. This study aimed also to corroborate previous findings on the capacity of wetland plants to tolerate highly toxic levels of trace elements, and to phytoremediate contaminated sites.

2. Materials and methods

2.1. Study area

The study area was a coastal wetland (c. 50 ha) located on the outskirts of the town of Catania (Italy), (Fig. 1; 37°29′17.01′′N; 15°05′16.25′′E). Catania has a total population of 315,000 inhabitants, which reach 800,000 people with the whole metropolitan area. Specifically, the study area is the estuary of a 6-km watercourse that marks the southern border of the town, and was channelized to collect the municipal wastewaters from Catania. However, the quality of the water and related sediments is significantly affected by untreated discharges of domestic and industrial origins, which make this area highly contaminated. Other polluting sources included road run-off and illegal waste dumping. The annual flow range is 0.50–2.0 m^3/s, whereas annual rainfall and temperature are 600 mm and 18.0 °C, respectively. This wetland is subjected to continuous polluting inputs, and is characterized by luxuriant aquatic and semi-aquatic vegetation. The control area was selected within a nature reserve located 15 km south of the study area (37°24′00.81′′N; 15°05′23.34′′E). The levels of trace elements detected in plants from the control area (data not shown) were compared with the levels of concentrations analyzed in the study area (see Table 8, letter "K"). The control area hosted the same plant communities found in the study area.

2.2. Sampling

A total of 20 different plant species was collected in the study area, according to different life forms (Table 1). This implied the collection of species with different ecology (e.g. semiaquatic vs permanently submerged), biomass size, morphology and root systems (rhizomatous vs free-floating). The rate of uptake and accumulation is age-dependent in plant species (Kabata-Pendias, 2011). Specifically, with plant aging, sensitivity to trace elements increases but is more related to the functioning of photosynthetic tissues than to growth parameters (Skórzyńska-Polit and Baszyński, 1997). We sampled only mature plant individuals to neglect possible differences, due to age, in uptake and accumulation of trace elements among the different studied species. To reduce the potential action of environmental factors that may influence the uptake of trace elements, we also selected sampling plots with homogeneous environmental conditions (e.g. no recent rains or floods, sampling on sunny and not windy days, absence of waste). Collection of water, sediment and plant samples followed the general protocols reported in Bonanno and Cirelli (2017). Sampling was conducted in two months, April and October, and in two years, 2015 and 2016. Five sampling plots per each different species were randomly selected within an area of 1000 m × 500 m. The average sampling plot was a quadrate of 2 m × 2 m, and contained at least 10 different individuals of the same species to be collected. In each sampling plot, four mature plant individuals of a given species, four samples of sediments and four of water (1.0 L each) were collected. The plant individuals of all species were delicately and wholly uprooted with stainless steel tools, cleaned with linen cloths to remove extraneous materials (e.g. gross ground particles), and put in sterilized plastic bags. Sediment samples were collected from the top 30 cm of the upper layer through a Plexiglas corer (internal diameter 10 cm), and put in 1.0-L polyethylene bottles. Water samples were collected within a radius of 0.25–0.50 m from each collected plant individual, through 1.0-L sterilized glass bottles, and at a variable depth of 0.20–0.50 m from the bottom to the water surface. In total, we collected 400 different samples (observations) per each study month and year. All collected samples were gathered in PVC containers and kept at 3 ± 1 °C until laboratory analysis. Although the levels of some toxic elements were higher than the legal limits, no collected plant specimen showed symptoms of toxicity (e.g. impaired growth).

2.3. Chemical analysis

This study analyzed the concentrations of the trace elements As, Cd, Cr, Cu, Hg, Mn, Ni, Pb and Zn in water, sediments and plant organs of the studied species. Chemical analyses followed the procedures as reported in Bonanno and Cirelli (2017). Once in the laboratory, plant samples were first washed in running tap water to remove surface contamination, and then rinsed with bidistilled water to remove any further residual material on the surface. After that, plant samples were dissected into roots, stems and leaves, and put in a refrigerator at 4 °C until chemical processing. In case of rhizomatous species, roots and rhizomes were treated together, and called "roots". The weight of each dissected

Download English Version:

https://daneshyari.com/en/article/8860090

Download Persian Version:

https://daneshyari.com/article/8860090

Daneshyari.com