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Trace element accumulation and distribution in the organs of *Phragmites australis* (common reed) and biomonitoring applications

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ABSTRACT

The concentrations of trace elements were studied in roots, rhizomes, stems, and leaves of *Phragmites australis* stands (common reeds), and in the corresponding samples of water and sediment from the mouth of the Imera Meridionale River (Sicily, Italy), an area affected by massive urbanization and intensive agriculture. The elements considered were Ag, Al, As, B, Ba, Be, Co, Fe, Mo, Pd, Pt, Rh, Sb, Se, Sr, Tl, and V. Concentrations in belowground organs were usually higher than aboveground tissues, and the general decreasing trend of element content was root > rhizome > leaf > stem. Trace element mobility was generally higher within the organs than in sediment to plant. Regarding Al, Fe, and V, the phytotoxic levels in roots and the low plant/root mobility, may indicate that roots are inherently tolerant to these metals, and act as filters to prevent toxic distribution in the plant. The high uptake of Pd and Rh showed that emissions of catalytic converters are one of the main health hazards of the study area. *P. australis* showed a direct response to the environmental conditions, and its application as a biomonitor should be considered.

1. Introduction

Macrophytes are widespread plant species showing suitable characteristics for pollution biomonitoring, especially of trace elements (Demirezen and Aksoy, 2006; Vymazal et al., 2007). The bioavailability of trace elements for plants is dependent on many environmental factors: concentrations in the environment, abiotic factors, exposure time, growth form of the plant, type of absorption mechanism, affinity of trace elements for the adsorption sites, element speciation, sampling period (Mazej and Germ, 2009). Trace elements in aquatic systems tend to become associated with particulate matter, which settles and accumulates in bottom sediments. Most rooted macrophytes uptake chemicals primarily from sediment pore water. To the extent that trace elements occur in the overlying water column, uptake by above-sediment plant parts is also possible (Cardwell et al., 2002). Regarding free floating macrophytes, this would be the only source of elements.

Phragmites australis (common reed) is one of the most distributed macrophytes in aquatic ecosystems, and numerous studies showed its capacity of trace element bioaccumulation (i.e., Duman et al., 2007; Bragato et al., 2009; Maddison et al., 2009). *P. australis* (Cav.) Trin. ex Steud., known as common reed, is a large perennial grass living in lakes and rivers or brackish wetlands such as marshes, across temperate and tropical regions all over the world (Pignatti, 1982). It belongs to the Poaceae family and is the most common species of the *Phragmites* genus. This species prefers eutrophic and stagnating waters, and tolerates a moderate salinity (Cooper et al., 1996). It is a rhizomatous hemicryptophyte/geophyte and forms wide stands known as reed beds that provide microhabitats for many birds and mammals.

The concentrations of chemical elements in aquatic plants can be more than 100,000 times greater than in the associated water (Albers and Camardese, 1993), and certain macrophytes can thus be used as indicators of low level contamination that might otherwise be difficult to detect. Currently, scarce data are available in literature about the use of *P. australis* as a potential bioindicator of growing concern elements such as Pd, Pt, and Rh, released by car catalytic converters. In particular, data about these elements are generally rare, and in most cases the determination has been mainly conducted in tunnel/street dust where undoubtedly the concentrations are highest (Djingova et al., 2003). This study, in turn, analyses the trace bioaccumulation in plant species collected in a natural environment (estuary), massively affected by urbanization. In the last few years, other elements, such as B, Ba, Mo, Sr, Tl, and V have gained special interest by conservationists for their adverse effects on the environment as fertilizers and pesticides as well as industrial pollution and sludge, with inevitable repercussions on the health of local communities (Kabata-Pendias and Mukherjee, 2007).

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Trace element biomonitoring using appropriate species as bioindicators may thus prove an essential tool for assessing the status of sensitive ecosystems, such as estuaries or aquatic environments in general, subject to urbanization and agriculture as main threats to biological integrity.

In this study, the concentrations of Ag, Al, As, B, Ba, Be, Co, Fe, Mo, Pd, Pt, Rh, Sb, Se, Sr, Tl, and V, were determined in roots, rhizomes, stems, and leaves of *P. australis*, and in the corresponding water and sediment samples, collected from the mouth area of the Imera Meridionale River (Sicily, Italy). The aims of this paper were:

(1) to quantify the concentration of different trace elements in roots, rhizomes, stems, and leaves of *P. australis*;
(2) to ascertain whether trace concentrations vary significantly according to the kind of organ;
(3) to determine the extent of element mobility from sediment to organs, and within the plant; and
(4) to test the organs of *P. australis* as potential bioindicators of trace element contamination in water and sediment.

2. Materials and methods

2.1. Study area

The site examined is the mouth of the longest Sicilian river named "Imera Meridionale" or "Salso" because of the high salinity of its waters (Fig. 1). The study area is 2 km long, affected by massive urbanization due to the town of Licata (37°06′54″ N–37°06′03″ N, 13°56′05″ E–13°56′52″ E). The annual mean temperature and rainfall are 18 °C and 430 mm, respectively, and this makes the study area one of the driest zones of Sicily. Rocks are largely alluvial and fluviolacustrine deposits of the Holocene. Main human activities are tourism and agriculture, especially greenhouse cultivation.

2.2. Sample collection

Twenty sampling points, namely 10 per river side, were randomly chosen along a 2 km gradient. Samples considered were plant, water and sediment. In each sampling point, 4–6 samples of *P. australis* were collected within a 5×2 m^2 plot. All the plant species had same habit with an average height of 2 m. Sampling of the plant material was conducted in areas bordering the river bank, and subject to periodic flooding. After the collection, plant and sediment samples were put in plastic bags sealed to avoid extraneous contamination. In particular, sediment samples were collected using a stainless steel collector at about 20–30 cm depth. Plant samples were washed in the river water to remove sediments. A number of 5 water and sediment samples were collected at each sampling point. Water samples were collected where water was 0.5–1 m deep on average, and 1–2 m far from the river bank. Water samples were kept in one-litre clean polyethylene bottles. Samples were transported in a cool box (5 ± 2 °C) to the laboratory the same day of the collection. Climatically identical days were chosen in order to exclude the influence of weather conditions. In particular, days were sunny and not windy. The sampling program was conducted in 4 periods: August 2007–2008 and September 2007–2008. The months of August and September were chosen because they coincide with the peak of the vegetative period of the common reed during which trace element concentrations generally show the highest values in the plant tissues. Each sampling point was surveyed once a month.

2.3. Sample analysis

Plant samples were preliminarily dissected in roots, rhizomes, stems and leaves; in particular, stem samples were prepared by considering the whole stem. Samples were then dried to a constant weight, and ground into fine powder in an agate mortar. Homogenized material (250 mg) was mineralized in a microwave oven (Milestone Ethos 1600) with HNO_3 and H_2O_2 (3:1) under high temperature and pressure. Mineralized samples were analyzed for Ag, Al, As, B, Ba, Be, Co, Fe, Mo, Pd, Pt, Rh, Sb, Se, Sr, Tl, and V, using Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

Fig. 1. Location of the study area.