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Assessment of airborne heavy metal pollution by aboveground plant parts

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Abstract

Italian stone pine (*Pinus pinea* L.) and oleander (*Nerium oleander* L.) leaves, bark and wood samples were collected at different sites around an industrial area (Huelva, SW Spain) and compared with samples of the same species from a background site. Samples were analysed with respect to the following pollutants: Al, Ba, Cr, Cu, Fe and Pb by ICP-AES. The suitability of different plant parts as biomonitors of pollution was investigated. In pine samples from the polluted sites the ratio of concentrations between bark and wood was high for Al, Ba, Cu and Fe, whereas no differences were found in samples from the unpolluted area. No differences were detected in oleander for the same ratio. In the oleander species, the ratio between leaves and wood concentration allowed to distinguish between control and polluted sites. The ratio of the concentration between leaves and wood was elevated for Al, Ba and Fe in pine samples from the polluted sites. The ratio of the concentration in bark or leaves to their concentration in wood might be useful to detect inorganic atmospheric pollutants.

Keywords: Leaves; Bark; Wood; Heavy metals; Airborne pollution

1. Introduction

Element distribution in leaves, bark or wood can vary and total element contents in above ground parts of the plant depend on root uptake and on element retranslocation from assimilation organs (Zimcka and Stackurski, 1994). Garland et al. (1981) suggested that the distribution of elements in various vegetative tissues (exclusive of stems) is a characteristic of xylem transport and that the ultimate concentration of an element in a specific tissue is related both to the flux of transpirational water lost through evapotranspiration and to the duration of this process for specific tissues. It has also been suggested that direct uptake through bark or foliage may be a major pathway by which metals enter trees, particularly in heavily polluted areas (Baes and McLaughlin, 1987).

The use of plant leaves as biomonitors is well known as widely reported in literature. Other parts, such as wood, have received less attention in what concerns atmospheric assessment. Tree bark, which accumulates atmospheric pollutants through wet and dry deposition, has been found to be a useful bioindicator and biomonitor for airborne pollution monitoring (e.g. Böhm et al., 1998; Bellis et al., 2001; Harju et al., 2002; Pacheco et al., 2002; Åberg et al., 2004; Migaszewski et al., 2005; Mingorance et al., 2005) and wood was also used in contamination studies (Meers et al., 2005; Saarela et al., 2005; Samecka-Cymermam et al., in press). Previous studies demonstrated that

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Nerium oleander L. and *Pinus pinea* L. are suitable to assess the heavy metal pollution in industrial areas (Sawidis et al., 1995; Aksoy and Öztürk, 1997; Rossini Oliva and Mingorance, 2004; Mingorance et al., 2005). Metal accumulation in bark and plant foliage in urban and industrial areas can be considerable, with the greatest amount of the heavy metal burden located in the bark (Cêburnis and Steinnes, 2000; Watmough and Hutchinson, 2003).

For any particular target element, ratios of concentrations between plant parts can be useful to give information concerning the different accumulation in each one and to suggest if there is a free movement of the elements between the parts. In addition, according to Saarela et al. (2005) the ratio bark/wood allows to exclude the variation in bark concentration due to local soil pollution or soil geochemistry.

Huelva area (SW Spain) is contaminated by several heavy metals due to local chemical and petrochemical industrial emissions. Main pollutants are Al, Ba, Cu, Cr, Fe, Mn and Pb (Querol et al., 2002; Mingorance et al., 2005).

The aim of this study was to encompass which plant parts (leaves, bark and wood) are suitable as bioindicators of pollution. The knowledge of the elemental content of wood, bark and other plant related materials could be of great interest for industrial and environmental authorities, since monitoring with plants supplies low-cost information on the environmental quality and quantity.

2. Materials and methods

The sampling was performed during the spring of 2002–2003. Leaves, wood and bark samples of both species were collected randomly along four transects (NE, SE, NW and SW) around the industrial complex of Huelva (SW Spain) and in a background site (Bk) (Rossini Oliva and Mingorance, 2004). Sampling sites were located at 0.5, 1, 2, 4, 6, and 8 km from the industrial complex (Punta del Sebo, Fig. 2) responsible of the main contamination source. The background site represents a rural area without any human activities and traffic, located 50 km far away from the studied area.

At each of the collection sites both species were sampled; each sample was taken from four plants. Whole bark samples of both species were taken from the external surface of bark by using a stainless-steel knife and once in the laboratory the inner part (wood) was separated; the thickness of the bark samples was about 2 mm. Bark samples were taken from the stem at a height of 1.5–2 m above the ground for pine and 1–1.5 m for oleander from all sides of the plant. The collected leaves and barks were not cleaned because the purpose of the study was to estimate the ability of plant parts to reflect the direct effect of atmospheric pollution; all samples were dried in an oven at 70 °C during 48 h and then milled. The total metal concentrations of Al, Ba, Cr, Cu, Fe, Mn and Pb were determined after digestion with nitric acid + hydrogen peroxide in a

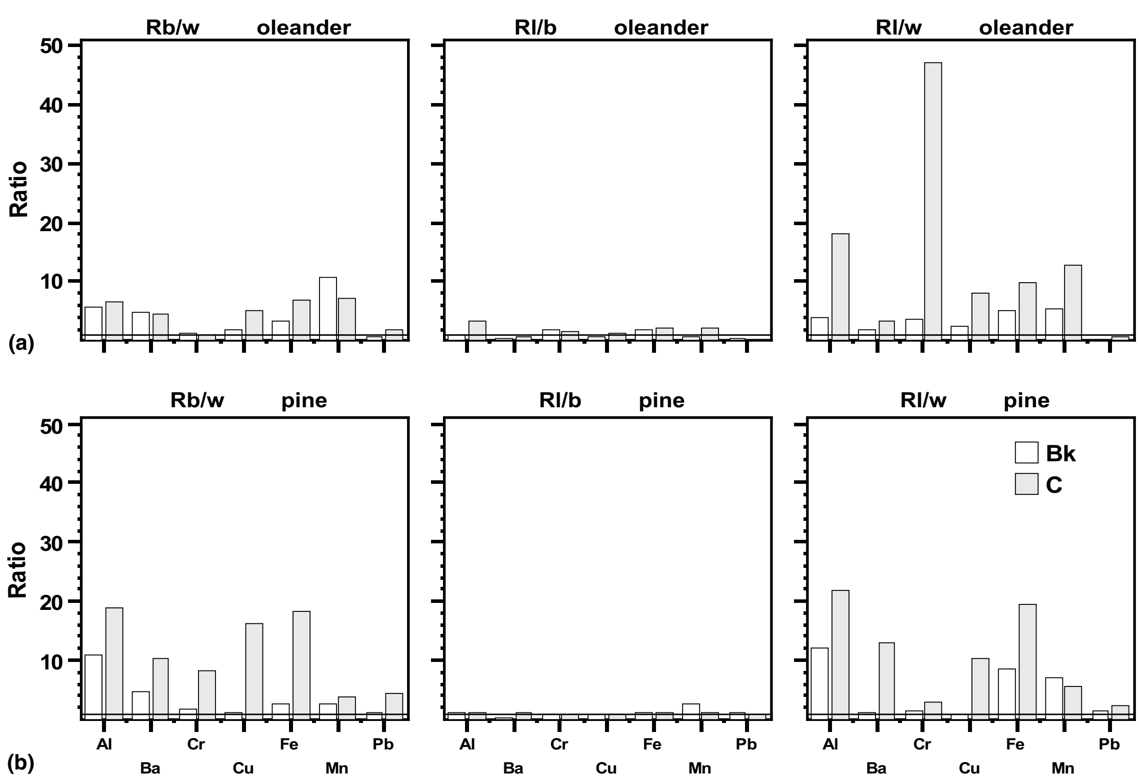

Fig. 1. Ratios (R) for all elements in contaminated (C) and background (Bk) sites. TF_b, ratio bark/wood; TF_{lb} ratio leaves/bark; TF_{lw} ratio leaves/wood. Horizontal line indicates value of $R = 1$.