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Leaves of *Pittosporum tobira* as indicators of airborne trace element and PM_{10} distribution in central Italy

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Abstract

Leaves of the evergreen ornamental shrub species *Pittosporum tobira* were used as a passive monitor to describe the distribution of selected elements in three coastal cities of central Italy (namely Livorno, Rosignano Marittimo and Piombino) differing for number of inhabitants and economical activities. Unwashed healthy mature leaves collected in June 2004 from 88 sampling sites covering the whole municipalities according to a systematic stratified unallineated sampling design were analysed by ICP-MS for Al, Ba, Be, Bi, Br, Ca, Cd, Cl, Co, Cr, Cs, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Si, Ti, V and Zn. Values were normalised by subtracting baseline concentrations of biologically essential elements. Enrichment factors were calculated taking Al as crustal reference element. Factor analysis allowed to identify three main source groups of elements, namely crustal components, sea-salt spray and anthropogenic sources (vehicular traffic, industrial activities). SEM–EDX analyses were performed on 556 PM_{10} samples collected from the 88 sampling sites. High contributions of geological elements and marine aerosols were detected. Pb is no longer of environmental concern in the area. Results are discussed with emphasis on the potential role of vegetation for the removal of particulate pollution.

Keywords: Factor analysis; ICP-MS; Pollution removal; Pollution sources; SEM–EDX; Source apportionment

1. Introduction

Ambient air has always contained particles, ranging from sub-micrometric aerosols to clearly visible dust and sand grains (Aitken, 1888). Natural and anthropogenic sources emit potentially toxic chemical elements into the atmosphere, often in the form of fine and ultrafine particles, which are now identified as responsible of deleterious effects on human health. Interest in particulate air pollution and its health effects has reached an extraordinary extent in recent years and this is presently the most intensively researched and hotly debated aspect of environmental toxicology. A report of the World Health Organization, which looked at vehicular emissions of particles in three European countries, revealed that more people were killed prematurely by the effects of these pollutants than through car accidents (WHO, 1999). More generally speaking, many epidemiological studies have revealed a clear

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association between elevated ambient concentrations of fine particulate matter and increased mortality and morbility in humans (Dockery and Pope, 1994). Problems associated with particles in the air became of public concern and on 1 January 2005, a new EU threshold was set for a maximum average of 50 μg of particulate matter (in terms of PM_{10}, i.e. the fraction of aerosol particles with an aerodynamic diameter less than 10 μm) per cubic metre of air over a 24-h period, which cannot be exceeded more than 35 days over the course of a year (this is approximately equivalent to the 90th percentile of daily means in a calendar year), as well as a threshold of $40\,\mu g\,m^{-3}$ ($20\,\mu g\,m^{-3}$ by 2010) for the annual average concentration (EU Directive 1999/30/EC).

Plants have evolved to maximise light interception and carbon dioxide assimilation and as a consequence they are also highly efficient receptors of airborne pollutants; the use of plant tissues has since long been shown to be an effective indicator of metal air pollution (Goodman and Roberts, 1971). Moreover, vegetation is an effective indicator of the overall impact of air pollution, and the effect observed is a time-averaged result, which is more reliable than the one obtained from direct determination of the pollutant in air over a short period.

The focus of the work reported herein is to quantify the role of vegetation in detecting the spatial distribution of selected elements and in particulate trapping, with special emphasis on plant species which are likely to be planted in urban environments. A widespread broadleaved evergreen ornamental shrub, *Pittosporum tobira* (Thunb.) Aiton, was selected as test plant, as it has been demonstrated that, as a result of their larger leaf area and the turbulent air movements created by their structure, trees and shrubs intercept more air pollutants, including particles, than shorter vegetation (Fowler et al., 1989; Beckett et al., 2000). This species has already been profitably used for investigating the bio-accumulation of selected trace elements in Sicily (Matarese Palmieri et al., 2005). Factor analysis was used to identify major sources of particles intercepted by leaves.

2. Materials and methods

2.1. Study areas

The Tuscan municipalities of Livorno (LI) (ca. 155,000 inhabitants), Rosignano Marittimo (RM) (ca. 30,000 inhabitants) and Piombino (PB) (ca. 35,000 inhabitants) were selected for this study. All of them are active centres along the Tyrrhenian sea, characterised by heavy vehicular traffic, consistent industrial activities and thermoelectric power plants. LI hosts a major commercial harbour, a large oil refinery, a solid waste incinerator and several small- and medium-sized enterprises. RM is the location of a large petrochemical plant and basic chemistry facilities, operating in fields such as sodium bicarbonate, sodium hypochlorite, peroxides and hydrochloric acid. PB area is a promontory and has a very long history as a steel-working pole and is an active passenger harbour. The climate of the area is sub-Mediterranean, with a dry summer and with a mean annual rainfall over a range of 700 mm. A sea-to-land and vice versa breeze system is the dominant anemological regime, but significant winds come from the western quadrants (i.e. perpendicular to the coast). Each municipality was divided into regular sectors (squares of 3×3 km: 34 squares for LI, 30 for PB and 24 for RM) and in each sector a sampling point was randomly selected according to a systematic stratified unallineated sampling design.

2.2. Plant sampling

Uniform 1-year-old leaves of *P. tobira* were collected from hedges and shrubs naturally present in the investigated areas. Care was taken to avoid leaves with clear imperfections such as insect infestation, presence of honeydew, bird dropping, pesticide treatment, chlorosis or necrosis, coarse and anomalous dust cover. Whenever possible, sampling was carried out at an height of 60–90 cm from ground and from the side of the edge facing the road. To evaluate total deposition, leaves were not washed. Sampling was carried out in the second week of June 2004, during stable anticyclonic conditions after a prolonged period of drought (more than 5 weeks without rain). It has been shown that rain may partially get rid leaves of deposited dust, but the resulting wet surfaces may then have higher interception rates (Chamberlain, 1967). A typical sample was represented by ca. 200 g of fresh material collected from three nearby plants. Samples were quickly transferred to the lab, oven-dried (75 °C) and ground to a fine powder.