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Air biomonitoring of heavy metals and polycyclic aromatic hydrocarbons near a cement plant

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ABSTRACT

Biomonitoring studies, based on pollutant accumulation analyses in tree leaves, allow evaluating the impact caused by air–dispersed pollutants on ecosystems, providing useful data, complementary to those obtained by instrumental monitoring. In particular, leaves of sclerophylls present morphological characteristics, such as the presence of hairs and of a tick cuticle, making them particularly useful in bioaccumulation studies. The first aim of this research was to compare heavy metal (HM) and polycyclic aromatic hydrocarbon (PAH) leaf accumulation capabilities of two Mediterranean tree species. The second aim was to evaluate the impact of a cement plant and/or of other anthropogenic activities occurring in industrial and urban areas on HM and PAH depositions. For these purposes, holm oak (*Quercus ilex* L.) and olive (*Olea europaea* L.) leaves collected along a transect industrial–urban–remote sites in southern Italy were employed. A different accumulation degree was observed for the two species. For HMs, *Q. ilex* leaves had the highest concentrations. The results showed that the influence of the cement plant emissions on pollutant concentrations was substantial in the area closer to clinker production and storage with the highest Pb, Ni, V, Cr, Fe, indeno(1,2,3–c,d)pyrene, benzo(*g,h,i*)perylene and benzo(*a*)anthracene leaf concentrations. However, *Q. ilex* leaves showed high HM and PAH concentrations also in the urban site, in relation to vehicular traffic emissions and depositions. The comparison of the results of the present study with those from the literature indicates that the overall air quality of the studied sites is not particularly compromised, also in proximity of the cement production. The use of holm oak should be preferred in biomonitoring due to its wider distribution compared to *O. europaea*.

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1. Introduction

Heavy metals (HMs) and organic compounds, such as polycyclic aromatic hydrocarbons (PAHs), as well as dust and other pollutants, have been identified in the emissions from cement plants (Koren and Bisesi, 2003). The use of solid wastes, as supplementary fuel or as raw material substitute, and several processes associated with cement manufacturing result in high emissions of HMs. In spite of the fact that metals are frequently blocked within the clinker, some of them are volatilized and condense on the dust particles (Schuhmacher et al., 2002; Isikli et al., 2003; Isikli et al., 2006). Estimated atmospheric emissions of As, Cd, Cr, Ni and Pb from cement production were of 124, 116, 692, 769 and 892 tons, respectively in Europe for the year 2000 (Pacyna et al., 2007). Al, Be, Cu, Mn and Zn have also been distinguished in the emissions from cement plants (Schuhmacher et al., 2002). In addition, combustion processes and in particular cement manufacturing have been pointed out as one of the most important sources of PAHs released into the atmosphere (Kaantee et al., 2004). However, the emissions of PAHs (quantity and type) linked to cement production depend on the fuel, the manufacturing process and the pollution control devices. The emissions can be transported through air mass movements, deposited at local and long–range, determining impacts and imbalances in the receiving environment. HMs and PAHs are toxic pollutants altering ecosystems. They are hazardous for human beings as particles to which these pollutants are associated can be inhaled and ingested (Domingo, 1994; Chang, 1996; IARC, 2013).

Studies on the degree of environmental contamination due to cement plant activities and the subsequent impacts on ecosystem health (Orecchio, 2010) are scarce. Some studies highlighted the negative impact of cement dust on soil community and the effect of the altered soil composition on vegetation growth (Ade–Ademilua and Umebese, 2007).

To evaluate the environmental quality and the impact caused by air–dispersed pollutants on ecosystems, tree leaves have been widely and effectively employed in biomonitoring studies, as alternative to instrumental monitoring. Although a quantitative relationship between air and plant concentrations of pollutants is not yet established, leaf content of pollutants mirrors their air concentrations (Alfani et al., 2000; De Nicola et al., 2011), providing time–averaged information on air contamination trends (Kardel et al., 2011). Moreover, biomonitoring can provide high spatial resolution because plants are widely distributed and relatively inexpensive. Tree leaves in particular are efficient in trapping gaseous and particulate air pollutants depending on leaf characteristics. Morphological and physiological leaf characteristics affect scavenging efficiency of air pollutants (Howsam et al., 2000). Leaves of several evergreen and deciduous tree species may be used as biomonitors for both inorganic and organic pollutants (De Nicola et al., 2011; Tomasevic et al., 2011).

The main goals of the present study were (i) to compare HM and PAH leaf accumulation capabilities of two Mediterranean tree species, namely holm oak (*Quercus ilex* L.) and olive (*Olea europaea* L.), collected along a transect industrial–urban–remote areas; (ii) to evaluate the impact of a cement plant and/or other anthropogenic activities occurring in industrial and urban areas on

HM and PAH depositions at local scale. The two selected species are widely spread in Mediterranean regions. *Q. ilex* represents the potential natural vegetation community in remote areas, and in urban areas it is used as ornamental plant. *O. europaea* is present as a wild and domestic tree in anthropogenic and rural areas. Both species can have leaves up to 3–4 years old and they display morphological adaptive characteristics (xeromorphism) in response to environmental constraints under Mediterranean climate, such as the presence of hairs and a tick cuticle. These characteristics are particularly useful in biomonitoring: the lifespan facilitates pollutant accumulation over a long period, the star–like trichomes on abaxial surface enhance the scavenging and retention of airborne particulate, whereas the cuticular waxes promote the accumulation of lipophilic organic pollutants (De Nicola et al., 2005, Sawidis et al., 2012).

2. Materials and Methods

2.1. Sampling

Sampling was carried out in May 2008 inside the area of the Italcementi Group cement plant (A, B, C, and D) and in other four sites, in particular in urban (E), industrial quarry (F), rural (G) and remote (H) areas, all located in Salerno province, Campania, southern Italy (Figure 1, Table 1). The main wind directions in the studied area are reported in Figure 2 (Campania Region, 2010). Within the area of the cement plant, sites A and B were located along the main road access, site C near the clinker processing (milling, kiln and storage point), site D near truck stationing point. A plan of the cement plant reporting the energy and heat flows, as well as gaseous and particulate emissions, is shown in Figure S1 (see the Supporting Material, SM).

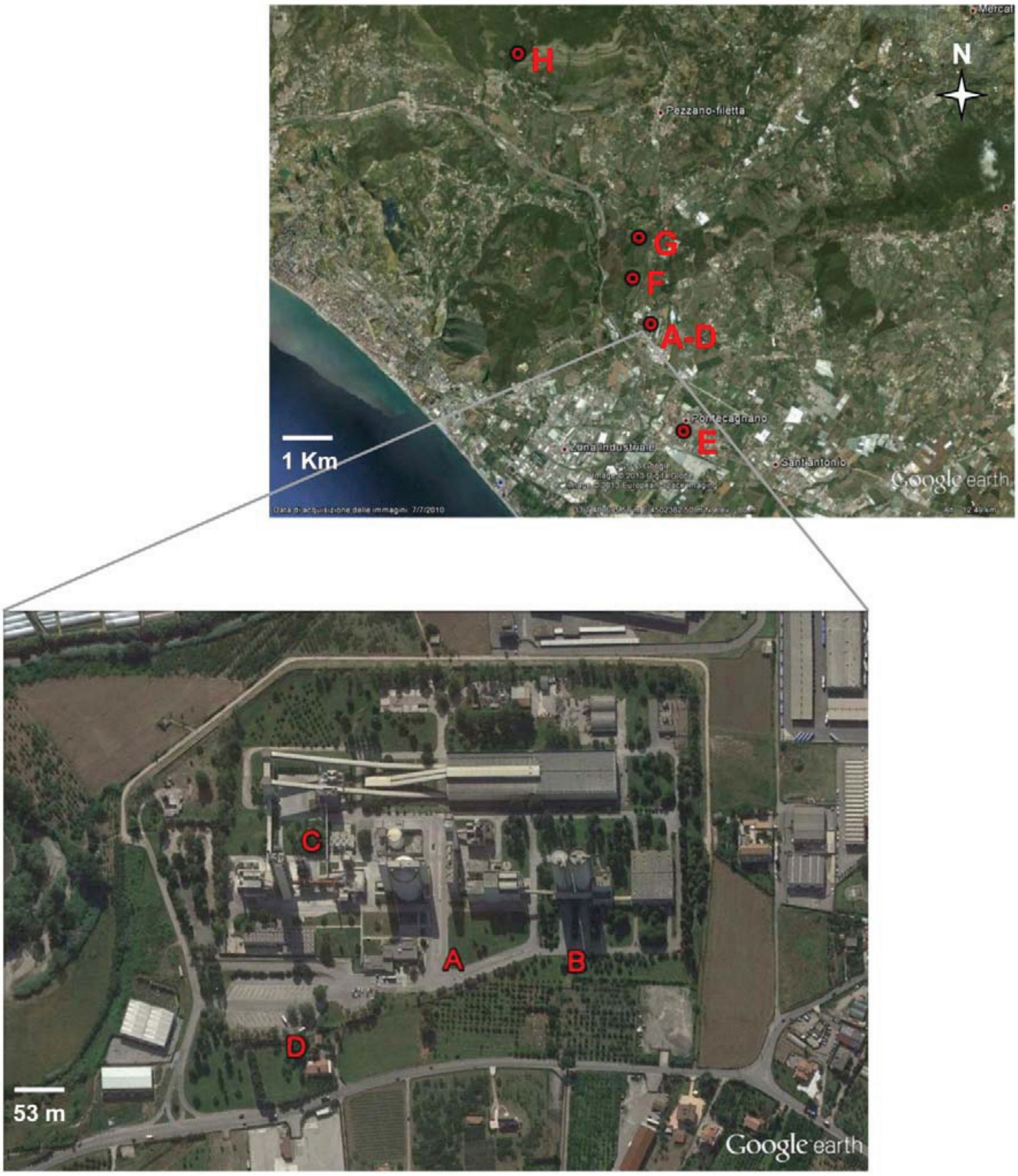

Figure 1. *Location of the sampling sites: cement plant (A-D), urban (E), industrial quarry (F), rural (G) and remote (H).*