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Biomonitoring of atmospheric pollution by moss bags: Discriminating urban-rural structure in a fragmented landscape

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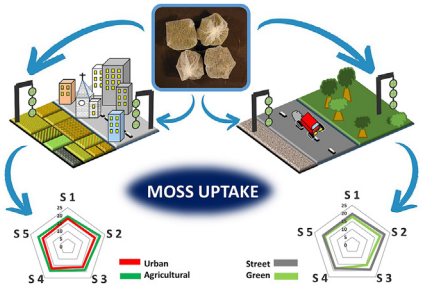
HIGHLIGHTS

- Moss bag sensitivity was tested in an urban-rural fragmented landscape.
- Moss uptakes were overall higher in agricultural than in urban sites.
- Mosses were able to discriminate between front road and matching green sites.
- Traffic and intensive agriculture are the major pollution sources in the study area.

GRAPHICAL ABSTRACT



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ABSTRACT

In this paper we investigated the possibility to use moss bags to detect pollution inputs - metals, metalloids and polycyclic aromatic hydrocarbons (PAHs) - in sites chosen for their different land use (agricultural, urban/residential scenarios) and proximity to roads (sub-scenarios), in a fragmented conurbation of Campania (southern Italy). We focused on thirty-nine elements including rare earths. For most of them, moss uptake was higher in agricultural than in urban scenarios and in front road sites. Twenty PAHs were analyzed in a subset of agricultural sites; 4- and 5-ringed PAHs were the most abundant, particularly chrysene, fluoranthene and pyrene. Overall results indicated that investigated pollutants have a similar spatial distribution pattern over the entire study area, with road traffic and agricultural practices as the major diffuse pollution sources. Moss bags proved a very sensitive tool, able to discriminate between different land use scenarios and proximity to roads in a mixed rural-urban landscape.

1. Introduction

Campania (southern Italy, one of the 20 administrative districts of Italy) experienced in the last century profound changes in land use, as a massive urbanization and increase of industrial

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settlements, especially in the surroundings of Naples city; it was recently reported that, if from the 1860 to the 1960 the urban/rural structure did not change substantially, in the last 50 years the urbanized area has multiplied its extension by a factor of five. At present, the urban area used by people for residential and productive activities covers approximately 40% of the entire Naples district, and the area devoted to agriculture the remaining 60%, producing a complex and jeopardized land (di Gennaro, 2014). This area, historically recognized as one of the most fertile Italian agricultural landscapes, in the last about 10 years was under the attention of media due to a supposed diffuse soil pollution by illegal waste dumping. A part of public and scientific opinion claims that this situation is the cause of increase of some cancer rates and shorter lifespan of people living there (Triassi et al., 2015), while, according to others, and based on the yearly "photograph" of health in Italy made by the Italian Institute of Statistics, Campania stats are progressively approaching those of industrialized northern Italian regions and Europe (ISTAT BES, 2014). Authoritative researchers have recently suggested that Campania could in fact be a perfect field study for a biomonitoring research program, as their poisoned fields could serve as a giant experiment in the new science of 'exposomics', but this suspected link needs to be investigated with appropriate methodologies (Nature editorial, 2014). Air composition and pollution are indeed affected by this complex patchwork of land use, degree of urbanization and spread of productive activities, with the problems related to waste cycle and vehicular traffic fluxes. European Union recognizes the poor air quality as the leading environmental cause of premature death in the EU. This aspect promoted at European level an extensive legislation to reduce harmful pollutant concentrations in ambient air that EU States, including Italy, are trying to fulfill in the last years. Presently, on the basis of European Air Quality Directives (2004/107/EC and 2008/50/EC), besides gaseous pollutants (e.g. NO_x, CO, O_3, SO_2) and particulate matter (PM), only other few atmospheric contaminants (e.g. Pb, Cd, As, Ni, Hg and benzo[a]pyrene) are continuously monitored. For example, the air quality monitoring network in Campania consists of 27 stations (plus other 9 located near the waste treatment plants) measuring a limited set of pollutants (e.g. NO_2, CO, PM_{10}, $PM_{2.5}$, O_3, SO_2, C_6H_6) (www.arpacampania.it).

The biomonitoring approach was widely used so far to evaluate the environmental quality and detect the presence in the air of inorganic and organic pollutants not routinely measured by conventional monitoring. This methodology is cost effective compared to physic-chemical approach, and can be applied with a flexible experimental design and a higher number of sampling points counterbalancing the lower precision of each single measurement. Particularly, in the last 40 years, mosses transplanted in bags, the so called "moss bags", were used to obtain indications of the inorganic and organic pollutant depositions, especially those linked to particulate matter (for a review see Ares et al., 2012). Surface interception and entrapment of airborne particulate matter is considered the principal pollutant accumulation pathway in mosses, favored by the high surface to mass ratio and cell wall characteristics (e.g. Tretiach et al., 2011).

In this paper, through a specific exposure design, we investigated the capability of moss bags to distinguish pollution inputs in sites with different land use (agricultural, urban/residential) and proximity to roads, in a fragmented landscape of Campania, where the two scenarios are strictly mixed together. An ample set of airborne pollutants (metals, metalloids and PAHs) was analyzed in moss exposed in 40 sites of five municipalities, all comprised in the "Litorale Domizio-Agro Aversano", recognized by the Italian State as a Regional Interest Priority Site (RIPS).

2. Materials and methods

2.1. The study area

The study area, comprised in the "Litorale Domizio-Agro Aversano", is characterized by a Mediterranean climate and covers five municipalities: Acerra (26 m.a.s.l., 54.71 km^2), Casal di Principe (68 m.a.s.l., 23.49 km^2), Giugliano in Campania (97 m.a.s.l., 94.62 km^2), Maddaloni (63 m.a.s.l., 36.67 km^2) and Teverola (25 m.a.s.l., 6.7 km^2); further details are described in Iodice et al. (2016) and Monaco et al. (2015). In 2004, the territory embracing the towns of Acerra, Nola and Marigliano was named the "triangle of death" by the medical magazine Lancet (Senior and Mazza, 2004) due to the claimed high incidence of cancer-related deaths. More recently, it is better known by the media as "land of fire", in reference to the numerous waste burnings (Legambiente report, 2003). Despite this perception encouraged by the media, the area, characterized by a still prevailing agricultural vocation, accommodates about 38,000 lively farms producing a 40% of the entire agriculture productivity of Campania (di Gennaro, 2014).

2.2. Biomonitoring survey

2.2.1. Experimental design, bags preparation and exposure

The methodology applied follows a protocol of exposure in which devitalized moss *Hypnum cupressiforme* Hedw. was used to prepare sub-spherical moss bags that were exposed in the sites of interest for six weeks (Ares et al., 2012 modified). The exposure design was applied to five municipalities of Campania RIPS – Acerra (Ac), Casal di Principe (C), Giugliano (G), Maddaloni (M) and Teverola (T) - taking into account the inventory of known emissions to the atmosphere (for more details see Iodice et al., 2016) and the diffuse conurbation of the area in which agricultural (A) and urban/residential (U) sites are strictly intermingled. At each municipality, two scenarios and four sites were selected: two agricultural (A1 and A2) and two residential/urban (U1 and U2). To put in evidence the effects of vehicular traffic emissions on pollutant uptake by moss, at each site the bags were exposed in two sub-scenarios: directly on the street (S) and at green areas (G) as small gardens, at least 20 m far from the street; this criterion was adopted due to the landscape configuration. So, finally, eight different exposure points were selected at each municipality (e.g. for Acerra, AcA1S, AcA1G, AcA2S, AcA2G, AcU1S, AcU1G, AcU2S, AcU2G, see Fig. 1 and Table S1), for a

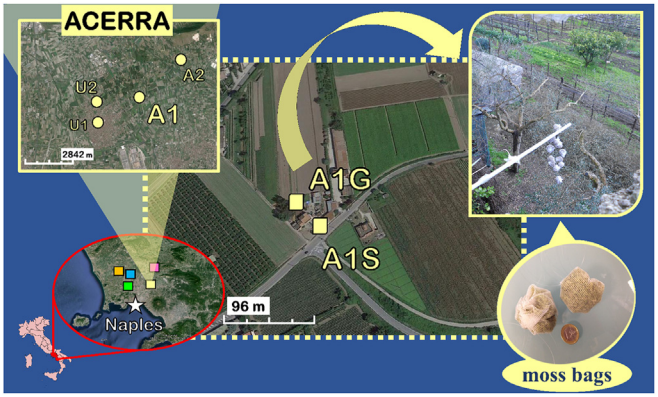

Fig. 1. Outline of the moss bag exposure design in the study area with a shoot up on Acerra agricultural (A1 and A2) and urban/residential (U1 and U2) sites. The arrangement of moss bags in green (G) and street (S) exposure points at the A1 site is also shown. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)