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Influence of population density on the concentration and speciation of metals in the soil and street dust from urban areas

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HIGHLIGHTS

- Population density increases dust/soil salinity.
- Population density does not affect on metals concentrations in soils.
- Population density increases metals concentrations in street dusts.
- Cu, Zn, Pb, Cr can be mobilized more easily from dust compared to soil.
- Population density increases Pb/Zn associated to reducible/carbonate phase in dust.

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ABSTRACT

Street dust and soil from high, medium and low populated cities and natural area were analysed for selected physical–chemical properties, total and chemical speciation of Zn, Pb, Cu, Cr, Cd, Co, Ni to understand the influence of human activities on metal accumulation and mobility in the environment. The pH, salinity, carbonates and organic carbon contents were similar between soil and dust from the same city. Population density increases dust/soil salinity but has no influence on metals concentrations in soils. Increases in metal concentrations with population density were observed in dusts. Cu, Zn, Pb, Cr can be mobilized more easily from dust compared to the soil. In addition, population density increase the percentage of Pb and Zn associated to reducible and carbonate phase in the dust. The behaviour of metals except Cd in soil is mainly affected by physico-chemical properties, while total metal influenced the speciation except Cr and Ni in dusts.

1. Introduction

Population growth, traffic emissions, municipal waste disposal and industrial activities are major causes of environmental pollution in urban areas (Saeedi et al., 2012; Bi et al., 2013). Soils serve as sources and sinks for trace elements and such has been used as a key indicator of human disturbance (Burt et al., 2014). Surface soil and street dust are possible good indicators of accumulation of heavy metals (Yeung et al., 2003; Sezgin et al., 2004), because they are not biodegradable and can remain in the environment over long periods of time. Human exposure to metal pollutants in soils and street dust causes health hazards such as those affecting nervous, renal, cardiovascular and reproductive systems (Christoforidis and Stamatis, 2009), growth retardation in children or cancer (Jiries, 2003). Recent studies deal solely with soils (Imperato et al., 2003; Sun et al., 2010; De Miguel et al., 1998; Acosta et al., 2010; Loska et al., 2004; Acosta et al., 2011) or street dust (Baptista and De Miguel, 2005; Lu et al., 2009; Saeedi et al., 2012; Du et al., 2013; Li et al., 2013). Only limited studies are available that compare both soils and street dust (Ordoñez et al., 2003; Al-Khashman, 2004; Christoforidis and Stamatis, 2009) to predict human and ecological risk upon exposures to heavy metals.

Most trace metals settle down as surface dust from atmospheric depositions before its incorporation into the soil matrix. Thus, the extent of atmospheric contamination may be better revealed by street dust than by bulk soils (Bi et al., 2013). In contrast, street dust is easily re-suspended or adhered to human skin, being an advantage to assess environmental quality and health risk. However, road dusts are often removed by the municipal street cleaning, making it difficult to collect appropriate dust samples,

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and compounded by the short residence time to incorporate high concentration metals.

The principal objective of this study was to determine the influence of the population density in the physico-chemical properties including the total concentration and the chemical speciation of metals in soils and dusts. This information is expected to help environmental scientists and regulators to better understand the behaviour of metals in soils and dusts to manage the human and environmental risks of metals in the environment.

2. Material and methods

2.1. Study area and sampling collection

The study area includes three urban settlements and a natural land as control site located in Murcia Region (SE Spain). The climate of this region is Mediterranean semiarid with 18 °C annual mean temperature and 350 mm annual mean rainfall. Murcia city represents high density (HD = 498 person/km^2) while Totana and Abaran cities have medium (MD = 106 person/km^2) and low (LD = 27.8 person/km^2) population densities, respectively (Fig. 1).

The main economical activity of the three cities is an intense agricultural cultivation of lemons, oranges, cereals, and vegetables in the areas surrounding the cities. In addition, only in Murcia city there are two industrial areas located 5 km far away from the city, one in the northwest and the other in the southwest of the city, including concrete plants, automobile services, manufactories of paints, steel products and electrical materials. However, previous studies (Acosta et al., 2009) have reported that heavy metals generated from these industrial areas do not reach Murcia city, therefore it is not expected any effect in urban soils or dust come from these sources.

A total of 40 soil and 18 street dust samples were collected; 18, 8, 4, 10 soils and 6, 4, 3, 5 dust samples at HD, MD, LD cities and natural area, respectively. Soil samples were taken in the topsoil from urban parks with a soil spade while dust samples were collected by sweeping an area of 1 m^2 using a polyethylene brush. The sweep action was very gentle and directly into the plastic collection bag to avoid the re-suspension of dust (Acosta et al., 2011; Zhang et al., 2012; Du et al., 2013).

2.2. Analytical methodology

Soil and dust samples were dried for 48 h at 45 °C and passed through a 2 mm sieve. A split of each sample was ground using an agate mortar (RetschRM 100).

The pH was measured in a solution of 1:1 water/soil ratio (Soil Survey Staff, 2004) while the electrical conductivity (EC) was measured in a 1:5 soil/water suspension (Andrades, 1996). The equivalent calcium carbonate was determined using the Bernard's calcimeter. Organic carbon was determined by the dichromate method (Soil Survey Staff, 2004).

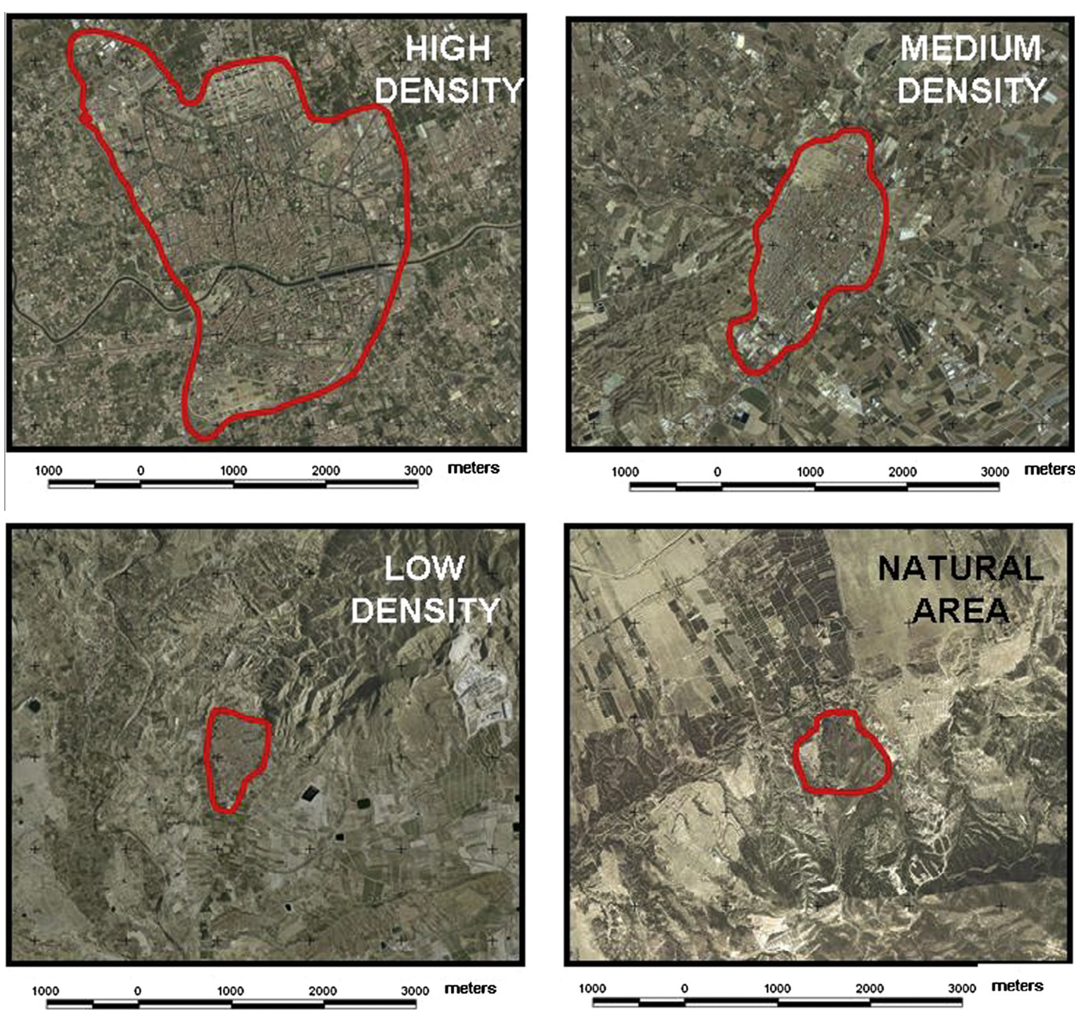

Fig. 1. Location of the selected cities.