Environmental Pollution 196 (2015) 156–163

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Impact of 70 years urban growth associated with heavy metal pollution

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ARTICLE INFO

Article history:
Received 28 July 2014
Received in revised form
1 October 2014
Accepted 16 October 2014
Available online

Keywords:
Retrospective analysis
Trace elements
Urban environment
Airborne pollution
Botanical garden
Herbarium specimens

ABSTRACT

Historical trends in trace element deposition were analyzed using herbaria specimens. We determined Al, Fe, Mg, Mn, Ca, Na, P, K, S, As, Cd, Cr, Cu, Ni, Pb and Zn contents in leaves of eight specimens collected in 1941. To assess changes, we collected the same plants from a botanical garden in 2012. The concentrations of major elements showed large species variability. However, temporal trends were predominately detected for heavy metals. The Cd, Ni and Cr contents in the 2012 leaves were 10, 13 and 16 times higher, respectively, than in 1941. Urban activities have substantially raised the levels of these metals in urban atmospheres due to changes in human activities over 70 years of urban growth. Nevertheless, Pb has decreased (−126%) in recent decades thanks to controlled lead fuel combustion. In short, metal deposition trend to increase Cr, Ni and Cd levels.

1. Introduction

A conceptual environmental problem associated with urban growth in space and time is increased pollution (Nriagu, 1990). Rapid urbanization and industrialization due to people migrating from rural areas to urban areas in the last few decades involve the demand for transport and energy, with increasing anthropogenic activities, such as vehicle traffic or industrial activities (Grigoratos et al., 2014), and this demand is directly involved with atmosphere anthropogenic emissions. Atmospheric pollution is one of the most important problems in urban environments (Fantozzi et al., 2013; Sawidis et al., 2011) and plays a vital role due to dry or wet deposition. Pollutants containing heavy metals are released from different anthropogenic sources, such as mining (Lv et al., 2014; Odumo et al., 2014; Rodríguez Martín et al., 2014), energy production (Rodríguez Martín et al., 2013b), industry (Kaitantzian et al., 2013) and combustion of fossil fuels in vehicle traffic (Argyraki and Kelepertzis, 2014; Sawidis et al., 2011). In the urban atmosphere, heavy metals (such as Pb, Zn, Cr, Ni or Cd) are released in different particles sizes (Argyropoulos et al., 2012), which can be primarily associated with traffic-related emissions due to incomplete fossil-fuel combustion from diesel-powered vehicles or industrial processes. The importance of this phenomenon needs to be viewed in the incessant urban growth context, which is common in most parts of the world (Lv et al., 2013) and can be linked to adverse health hazard effects (Kampa and Castanas, 2008; Kelepertzis, 2014).

Using trees as bioindicators of heavy metals pollution is a well-known practice which began in the 1970s (Smith, 1972). Before the 1970s, very little quantitative information was available to reconstruct long-term changes in metal deposition (Shotbolt et al., 2007). It represents a way to relate air quality with temporal concepts (Serbula et al., 2012). Vegetation absorbs gaseous compounds and accumulates airborne particulates (Escobedo and Nowak, 2009; Fantozzi et al., 2013), particularly on a local scale (Tallis et al., 2011), where atmospheric pollutants accumulate through wet and dry deposition in plants and soil. It is now well accepted that plants can be effectively used as biomonitors of heavy metal environmental pollution (Pacheco et al., 2002; Rossini Oliva and Mingorance, 2006). In some instances, an increase in heavy metals can cause damage to vegetation (Sawidis et al., 1995). Older studies on urban soils have identified high concentrations of heavy metals, especially Pb, in urban and garden soils (Wilkins, 1978) due to the use of leaded petrol, or this phenomenon has been attributed

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http://dx.doi.org/10.1016/j.envpol.2014.10.014
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to coal and peat combustion for home heating in older residential areas (Zhang, 2006).

Preliminary studies have shown the possibility of using herbarium specimens to assess changes in heavy metal pollution (Ochota and Stebel, 2013; Shotbolt et al., 2007). Herbaria material can be used to carry out retrospective analyses to show the evolution of heavy metal pollution in past decades (Herpin et al., 1997; Peñuelas and Filella, 2002). Plant specimens stored in herbaria have been used to document the impacts of global change on humans and nature (Herpin et al., 1997; Lavoie, 2013), and have shown that heavy metal concentrations in herbarium specimen samples correlate with atmospheric inputs of heavy metals during the corresponding periods. However, some local differences between particular localities and species have been recorded in these research works (Ochota and Stebel, 2013). This problem can be caused by spatial variability due to the location of herbarium specimens in the field between sampling years. Variability between the different samples collected from herbaria does not exist when samples are collected from botanical garden herbaria and when the location of specimens is exactly the same during different periods. Botanical gardens in urban areas are an excellent tool to evaluate pollution, but very few studies exist in this research area. Hence it is necessary to consider the value of alternative resources to investigate past metal deposition, such as archived samples in herbarium collections (Shotbolt et al., 2007).

The aim of this study was to determine the levels of airborne heavy metal contamination (Cd, Cr, Cu, Ni, Pb and Zn) in plants using herbarium specimens and new samplings in botanical gardens to simulate the temporal process of urban growth from 1941 to 2012 in Valencia (east Spain). The extension of urban areas offers benefits, but can also create a negative environment, including increasing energy demand, traffic, pollution and human health problems. Another objective of this study was to reconstruct the past deposition trends of the accumulation of several trace elements by means of the Valencia Botanical Garden, presently located in the historic city centre, but its present location was originally on the city border, as a bioindicator of pollution.

2. Materials and methods

2.1. Study area and botanical garden

Valencia was traditionally an agricultural region with a vast production of horticultural products (known as the famous "Huerta de Valencia"). This region enjoys a Mediterranean climate, with an annual average temperature of over 17.5 °C and average annual rainfall of 440 mm year. The city of Valencia is located to the east of the Iberian Peninsula (Fig. 1) and is the third largest city in Spain. Traditionally, agriculture was the main activity, up until the last 30 years because, nowadays, 67% of the activity conducted in Valencia focuses on trade and services. Valera et al. (2012) indicate that a highly dynamic process has occurred given the extent of land developed as urban, commercial and residential areas. In 1956 only 3520 ha (9.5% of the Valencian metropolitan area) was occupied for

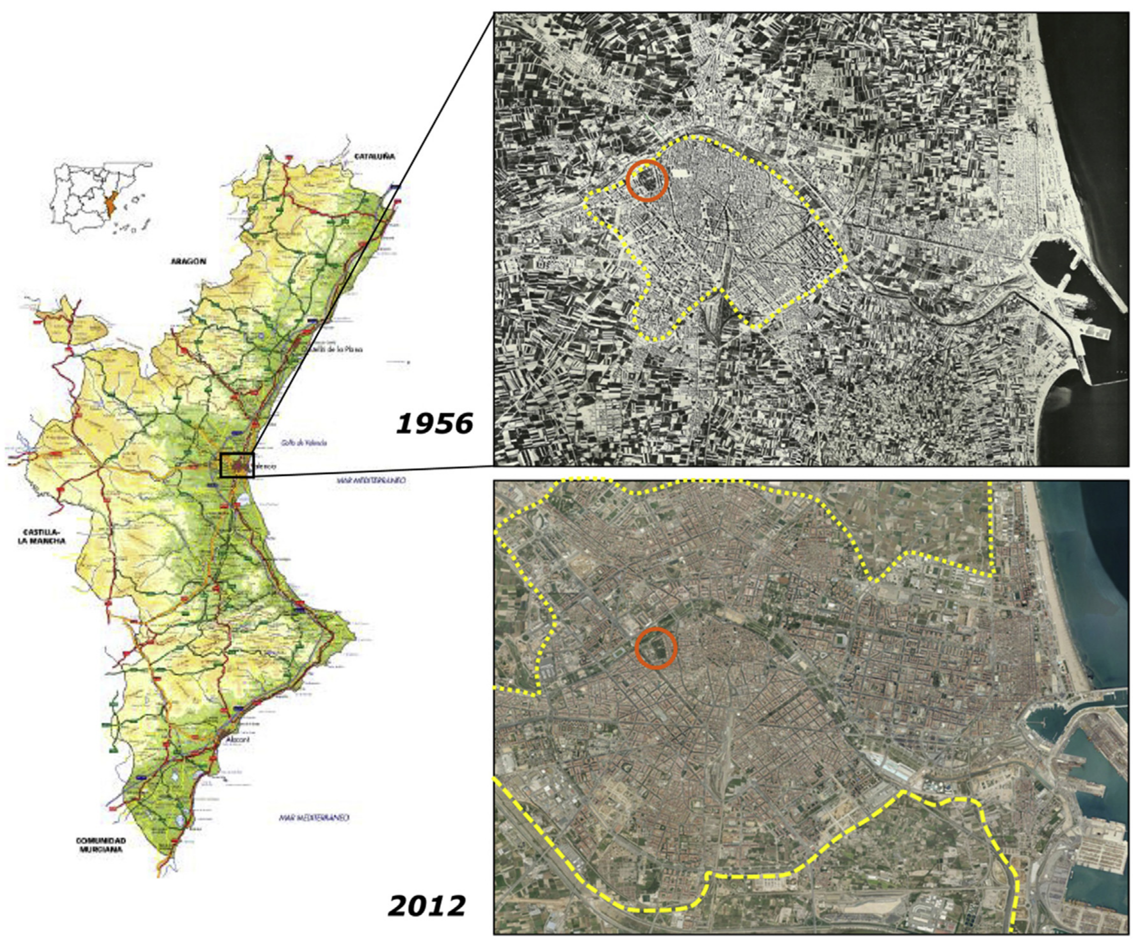

Fig. 1. Map of Valencia showing the City of Valencia. Aerial photography of the City of Valencia in 1956 and 2012, showing the location of its Botanical Garden. Discontinuous lines denote the limits of the city each year.