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Biomonitoring of atmospheric heavy metals pollution using dust deposited on date palm leaves in southwestern Iran

ZEINAB NADERIZADEH, HOSSEIN KHADEMI and SHAMSOLLAH AYOUBI
Department of Soil Science, College of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran
Corresponding author: H. Khademi; email: hkhademi@cc.iut.ac.ir

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RESUMEN

Los metales pesados presentes en el polvo causan problemas de salud en seres humanos y otros organismos. Los principales objetivos de este estudio fueron determinar: 1) las concentraciones y las fuentes de metales pesados (Zn, Cu, Pb, Fe, Ni, Cr, Co y Mn) y 2) los niveles de contaminación de metales en el polvo de Bushehr (zona urbana) y Assaluyeh (zona industrial), ubicados en la provincia de Bushehr al suroeste de Irán. Además, se estudió el transecto entre las dos ciudades como zona rural. Para ello se tomaron 50 muestras de polvo depositado sobre las hojas de palmera datilera así como 50 muestras de suelo superficial. Las concentraciones medias de metales pesados en el polvo fueron más altas que aquellas encontradas en los suelos cercanos, a excepción de Co en Assaluyeh y Pb en Bushehr. Por su parte, las concentraciones de Zn, Cu y Pb en las muestras de polvo de las zonas industrial y urbana fueron más altas que las de muestras tomadas en la zona rural. Además, los resultados indicaron un nivel de contaminación mínimo para Mn, Fe y Cr, de mínimo a moderado para Co, moderado para Ni, de moderado a significativo para Cu, significativo para Zn, y de significativo a muy alto para Pb en el polvo. Las dos principales fuentes de los diferentes metales pesados en el polvo atmosférico depositado en las hojas de palmera datilera se identificaron mediante análisis de componentes principales, análisis de clúster y análisis de correlación. Zn, Cu y Pb parecen provenir de fuentes antrópicas, mientras que las concentraciones de Fe, Ni, Cr, Co y Mn en el polvo atmosférico probablemente proceden de fuentes no antrópicas. En general, la implementación de estándares ambientales y la mejora del sistema de transporte público son acciones necesarias para reducir la emisión de contaminantes peligrosos a la atmósfera.

ABSTRACT

Heavy metals in dust are causing health problems in humans and other organisms. The main objectives of this study were to determine (1) the concentrations and the sources of heavy metals including Zn, Cu, Pb, Fe, Ni, Cr, Co and Mn, and (2) the contamination levels of metals in the dust of Bushehr (an urban area) and Assaluyeh (an industrial area) located in the province of Bushehr, southwestern Iran. Also, the transect between the two cities was investigated as a non-urban area. Fifty dust samples deposited on date palm leaves and 50 surface soil samples were collected. The mean concentrations of heavy metals in dust from the three areas were found to be higher than those of the nearby soils except for Co in Assaluyeh and Pb in Bushehr. Zn, Cu and Pb concentrations in dust samples from industrial and urban areas were higher than those in samples taken from the non-urban area. The results indicated minimal pollution levels of Mn, Fe and Cr, minimal to moderate levels of Co, moderate levels of Ni, moderate to significant levels of Cu, significant levels of Zn, and significant to very high levels of Pb in dust. The two main sources of different heavy metals in atmospheric dust deposited on date palm leaves were identified based on principal component analysis, cluster analysis and correlation analysis. Zn, Cu, and Pb seem to have anthropogenic sources, whereas Fe, Ni, Cr, Co, and Mn in atmospheric dust presumably derive from non-anthropogenic sources. In general, the implementation of environmental standards and improvement of the public transportation system are required to reduce the hazardous pollutants released into the atmosphere.

Keywords: Heavy metals, dust, palm, anthropogenic sources, pollution.

1. Introduction

Increasing industrialization and human activities intensify the emission of various pollutants into the environment (Onder and Dursun, 2006). Air pollution has been considered one of the most important environmental challenges because of its direct effect on ecosystems and human health (Nasiruddin Khan and Sarwar, 2014). Heavy metals pose serious environmental risks, which has encouraged extensive investigation (Onder and Dursun, 2006; Lu *et al*., 2010; Wei *et al*., 2010; Al-Khashman *et al*., 2011; Sawidis *et al*., 2011; Chen *et al*., 2014a, b).

Heavy metals are natural constituents of the Earth's crust. They are very stable and cannot be degraded or destroyed (Tokalioglu and Kartal, 2006). These metals enter the environment from many different anthropogenic sources such as industrial and agricultural activities, combustion of fossil fuels and energy production (Sawidis *et al*., 2011). In the urban atmosphere, heavy metals are released in the form of air particulates of different sizes in the range of 1 μm in solid and/or liquid states, and are directly dispersed into the atmosphere (Sawidis *et al*., 2011). Road vehicles can release a quantity of heavy metals into the air, water and soil. Therefore, vehicle emissions are considered one of the main sources of heavy metal contamination in urban environments (Duong and Lee, 2011). Heavy metals produced by vehicular exhaust and road, tire and brake abrasion can be deposited as road dust by dry or wet atmospheric deposition (Thorpe and Harrison, 2008; Duong and Lee, 2011). Present and former mining activities, foundries, smelters and diffuse sources such as piping, constituents of products, combustion of by-products, traffic, and industrial and human activities have been reported as the main anthropogenic sources of heavy metal pollution (Al-Khashman, 2004).

Heavy metals enter our bodies via food, drinking water, and air. As trace elements, some heavy metals (e.g., Cu, Se, and Zn) are essential for maintaining the metabolism of the human body. However, they are toxic at higher concentrations (Tokalioglu and Kartal, 2006). Several heavy metals such as Pb, Co, Cd, Cu, and Cr are considered as hazardous contaminants that could accumulate in the human body with a relatively long half-life (Salt *et al*., 1995). Moreover, some species of Cd, Cr, and Cu might be associated with health effects ranging from dermatitis to various types of cancer (Das *et al*., 1997; Onder and Dursun, 2006).

Atmospheric heavy metals can reach soil and plant leaves by dry and wet deposition, resulting in changes in their concentrations in both matrices (Maisto *et al*., 2004). Dry deposition of heavy metals and acidic compounds on plants increases during dry periods, and a stronger effect is detected after precipitation (Onder and Dursun, 2006). The materials deposited on leaves and needles affect chlorophyll, cell membrane, and stomata while they also reduce plant growth. Both dry and wet depositions cause the growth of main and side buds to stop, leaf color to fade, and some parts of trees to dry. These changes reduce the resistance of trees to drought, frost, insects, and fungi (Shanker *et al*., 2005; Onder and Dursun, 2006).

Recently, many studies have used trees for monitoring elemental deposition from the atmosphere. Many plant groups, including evergreen trees such as *Phoenix dactylifera* (Al-Khlaifata and Al-Khashman, 2007; Al-Khashman *et al*., 2011), *Populus alba* (Madejón *et al*., 2004), *Cedrus libani* (Onder and Dursun, 2006), and *Nerium oleander* (Dongarra *et al*., 2003) have been used for monitoring environmental pollution. The use of vegetation as a passive sampler in biomonitoring has the advantage of high spatial and temporal distribution due to the excellent availability of plants and low sampling costs (Sawidis *et al*., 2011). Trees are usually easier to identify as compared to other organisms such as fungi, algae, lichens, or mosses (Berlizov *et al*., 2007).

The date palm tree (*Phoenix dactylifera* L.) is the dominant species cropped in the southern parts of Iran. It is a monocotyledon of the family Palmae (Al-Shayeb *et al*., 1995) that is found in different regions including the USA, the Arabian Peninsula, Iran, and Pakistan. Date palm can survive in a wide range of temperatures (from 7 to 40 ºC) and grows in almost any type of soil (Al-Shayeb *et al*., 1995). Although the date palm tree has been previously used for monitoring heavy metal distributions in many countries (Al-Shayeb *et al*., 1995; Al-Khlaifata and Al-Khashman, 2007), the dry dust deposited on the surface of its leaves has not been used to estimate air pollution levels and to examine the effects of different factors (e.g., traffic and industry) on the distribution of air-borne heavy metals.

The objectives of this study were (1) to investigate the levels of heavy metals (Cu, Zn, Pb, Co, Cr,