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Pollution and health risk assessment of heavy metals in agricultural soil, atmospheric dust and major food crops in Kermanshah province, Iran

Shahab Ahmadi Doabi[a,*], Mahin Karami[b], Majid Afyuni[a], Mojgan Yeganeh[c]

[a] Department of Soil Science, College of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran
[b] Department of Soil Science, Faculty of Agriculture, Razi University, Kermanshah 6715685438, Iran
[c] Soil and Water Research Institute (SWRI), Agricultural Research Education and Extension Organization, Karaj 31785-311, Iran

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ABSTRACT

A total of 167 samples of agricultural soil, atmospheric dust and food crops (wheat and maize) were collected, and four heavy metals, including Zn, Cu, Ni, and Cr, were analyzed for their concentrations, pollution levels and human health risks. The mean heavy metal contents in the agricultural soil and atmospheric dust were exceeds background values and lower than their IEQS (Iranian Environmental Quality Standard) with an exception of Ni. A pollution assessment by Geo-accumulation Index (I_{geo}) showed that the pollution levels were in the order of Ni > Cu > Cr > Zn for agricultural soils and Ni > Cu > Zn > Cr for atmospheric dust. The Ni levels can be considered "moderately to heavily contaminated" status. The human health risk assessment indicated that non-carcinogenic values were below the threshold values (1), and main exposure pathway of heavy metals to both children and adults are ingestion. The carcinogenic risks values for Ni and Cr were higher than the safe value (1×10^{-6}), suggesting that all receptors (especially wheat) in Kermanshah province might have significant and acceptable potential health risk because of exposure to Ni and Cr. The carcinogenic risk for children and adults has a descending order of Ni > Cr, except for wheat. These results provide basic information on heavy metal contamination control and human health risk assessment management in the Kermanshah province.

1. Introduction

The potential public health risk associated with the intake of metals from dust and soil has been the subject of discussion in recent years (Wei and Yang, 2010). Heavy metals (HMs) in dust and soil can be easily transferred into human body via three routes: ingestion, inhalation and dermal contact (De Miguel et al., 1998; Madrid et al., 2002; Aelion et al., 2008; Li et al., 2013; Qing et al., 2015; Wu et al., 2015). Agricultural, industrial, and urban developments have raised the possibility of metals' accumulation in food crops and as a consequence, their risk for human health and well-being (Huang et al., 2007).

Pollutant metals are usually non-degradable and there is no known homeostasis mechanism for them. Thus, any high levels of HMs will threaten biological life (Tong and Lam, 2000). Many investigations have confirmed that HMs accumulate in fatty tissues and then affect the functions of nervous system, endocrine system, immune system, cardiovascular system, urogenital system, normal cellular metabolism, etc. (Waisberg et al., 2003; Bocca et al., 2004; Li et al., 2013; Wang, 2013) and significant negative effects on human health, ranging from acute reactions to chronic illnesses (Kampa and Castanas, 2008; Shi et al., 2008; Pei et al., 2015; Wang et al., 2015). The Chromium (Cr) is toxic or carcinogenic even at low concentrations when people are exposed for a long time (Angelone and Udovic, 2014; Khan et al., 2015; Zhang et al., 2015). The toxicity of Zn and Cu can change the function of the human central nervous system and respiratory system, and disrupt the endocrine system (Ma and Singhirunnusorn, 2012). Oral exposure to Ni can result in an increased incidence of allergic contact dermatitis, eczema, and respiratory effects in humans (ANL, 2001).

Heavy metals are ubiquitous in the environment, as a result of both natural and anthropogenic activities, and humans are exposed to them through various pathways (Wilson and Pyatt, 2007). According to numerous studies, the pollution sources of HMs in environment are mainly derived from anthropogenic sources. The anthropogenic sources of metals in urban areas include traffic emission (vehicle exhaust particles, tire wear particles, weathered street surface particles, brake lining wear particles), industrial emission (power plants, coal combustion, metallurgical industry, auto repair shop, chemical plant, etc.), domestic emission, weathering of building and pavement surface, atmospheric deposited (Sezgin et al., 2004; Ahmed and Ishiga, 2006; Morton-Bermea et al., 2009), and in agricultural areas include mining, waste disposal,

* Corresponding author.
E-mail address: shahabahmadi105@gmail.com (S.A. Doabi).

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sewage, pesticides, fertilizers, and vehicle exhausts (Montagne et al., 2007; Yu et al., 2008).

The perusal of related literature revealed that the few studies carried out in Iran were mostly focused on monitoring the concentrations, identifying the enrichment factors and sources, and assessing the pollution levels of HMs in the soil and dust (Saeedi et al., 2012; Kamani et al., 2015; Keshavarzi et al., 2015; Soltani et al., 2015; Ahmadi Doabi et al., 2017). However, there is no information available about health risk assessment of HMs for humans residing in Kermanshah province, Iran. Health risk assessment is an effective approach to determine the risk to human health quantitatively posed by several various contaminants through different exposure pathways (Kampa and Castanas, 2008; Luo et al., 2012). Therefore, to enact an effective policy to quantify and control further harm on human health risk by HMs, a comprehensive health risk assessment in agricultural soil, atmospheric dust and major food crops throughout Kermanshah province is needed.

Keeping in view the importance of health risk assessment, the current study aimed elaborate the following objectives: 1) to determine total concentrations of four heavy metals (Zn, Cu, Ni and Cr); 2) to assess levels of heavy metals pollution in agricultural soil, atmospheric dust on the basis of geo-accumulation index; and 3) to evaluate the potential non-carcinogenic and carcinogenic health risks of heavy metals for children and adults via different exposure pathways by using health risk assessment models described by United states Environmental protection agency (US EPA). To our knowledge, this study is the first attempt to assess the potential health human risk in agricultural soils, atmospheric dusts and major food crops of Kermanshah province.

2. Materials and methods

2.1. Study area

Kermanshah province is situated in the west of Iran. It is mountainous and the climate is arid and semi-arid (Fig. 1). The population of this region is about 1.94 millions. The annual mean precipitation and temperature in the province is 450 mm and 16 °C, respectively. The prevailing wind directions are west to east with northwest and southwest fluctuations (IRIMO, 2013). The gaseous wastes in the form of automobile exhaust, chemicals factories emissions, different kinds of industries (including oil refinery and petrochemical factory) and primitive forms of heating, as well as dust input from Iraq, the neighboring country, are the major sources of pollution in the province. In addition to high population growth rate, the rate of urbanization has also accelerated and is now one of the highest in Iran.

2.2. Sample collection and preparation

2.2.1. Agricultural soil and food crops sampling

Based on the predominant crop distribution, sizes of agricultural area, and probable sources of soil pollution, 53 agricultural soil samples (AS) were collected from 0 to 20 cm depth across Kermanshah province (including counties: Kermanshah, Sonqor, Gilan-e Gharb, Qasr-e Shirin, Sahneh, Sarpol-e Zahab, Kangavar, Paveh, Javanrud and Eslamabad-e Gharb) based on a randomized design in May 2013 (Fig. 1). Samples were taken from the designated locations by a process of composite sampling (quincunx sampling pattern), using a stainless steel auger. Five soil subsamples were taken and mixed together at each sampling point. These composite soil samples were transmitted to a central laboratory for physical and chemical analyses. All soil samples were air-dried at room temperature. After removing the stones and other debris, samples were passed through 2 mm polyethylene sieve. Portions of all samples (~50 g) were ground in a grinder and sieved through 0.15 mm (100-mesh) for soil heavy metal analysis (Micó et al., 2006; Lu et al., 2012). In addition, at the harvest time (July and September 2013), 16 samples from edible parts (grain) of wheat (10 samples) and maize (6 samples) were also collected from different areas of Kermanshah province in the same sites where soils were collected. Fields were chosen randomly considering the size of them and their crops.

2.2.2. Atmospheric dust sampling

A total of 98 atmospheric dust samples (AD) were collected in a temporal range from spring to summer 2013, each sample lasting 87 days in different cities of Kermanshah province (including counties: Kermanshah, Sonqor, Gilan-e Gharb, Qasr-e Shirin, Sahneh, Sarpol-e Zahab, Kangavar, Paveh and Javanrud) (Fig. 1). Kermanshah province meteorological organization statistics showed dusty days occur mainly in spring and summer seasons. The sampling sites were selected based on the following criteria. They were not shaded by trees or buildings, were easily accessible and secure against interference by animals, humans and upwind obstructions. Accordingly, dust collectors (passive samplers) were installed on the roof of buildings about 3–4 m above the ground level. Each collection tray consisted of a circular plastic surface (320 mm in diameter, 120 mm depth) fixed on holders with 33 cm height and were covered with a 2 mm PVC mesh on the top to form a rough area for trapping saltant particles. Dust samples were collected

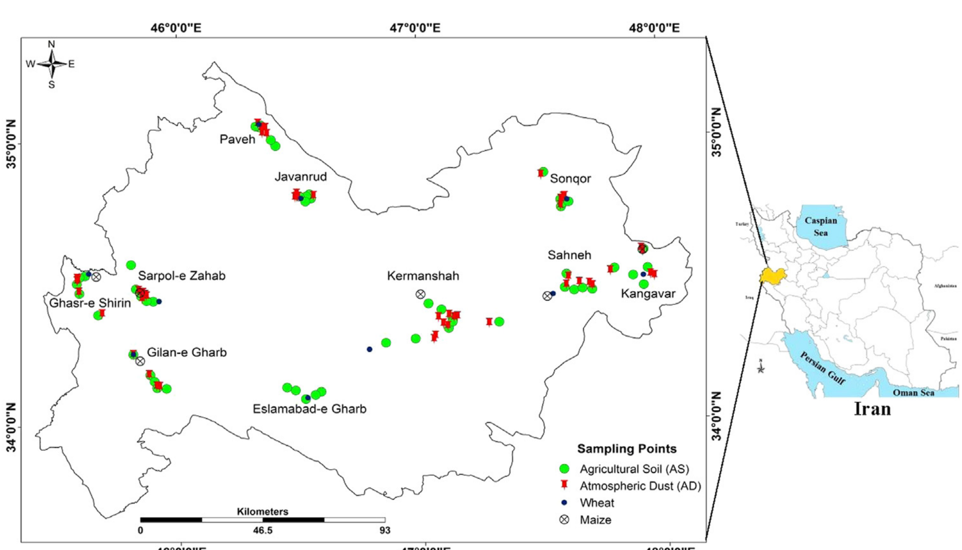

Fig. 1. Study area and sampling points in Kermanshah province.