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A geochemical survey of heavy metals in agricultural and background soils of the Isfahan industrial zone, Iran

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ABSTRACT

There is a growing public concern about the potential accumulation of heavy metals in agricultural soils of Iran. This is mainly the result of rapid urban, mining and industrial discordant development over the last several decades, which has jeopardized the ecology, food safety, human health, and sustainable development of agriculture. To investigate the soil pollution, a total of 105 agricultural soil samples and 40 background soil samples were collected from the Isfahan industrial zone. Accordingly, total concentrations of 7 heavy metals (including Cu, Pb, Zn, Cd, Ni, Co and Cr), associated with Al, Fe, Mn and some physicochemical properties of soils were determined. The geochemical background and threshold was predicted using the Median Absolute Deviation (MAD) method. The median concentrations of heavy metals in agricultural soil were nearly similar to those of background soil, with some outlier data in the vicinity of the industrial and mining areas. Based on correlation coefficient and factor analyses, the primary source of Ni, Co, Cr, Fe and Al was determined to be geogenic, whereas the source of Pb, Zn and Cd is substantially controlled by anthropic activity. Our observations proved that in the Isfahan industrial zone, both human and natural sources affect the concentrations of Cu and Mn. Maps of heavy metal pollution indices in agricultural soils reveal high level of pollution in the vicinity of $Bama_{Pb\text{-}Zn}$ mining area along with Esfahan and Mobarakeh Iron-Steel plants.

1. Introduction

Soil serves many vital functions in the ecosystem and is a fundamental resource for human survival and development (Li et al., 2008; Wong et al., 2002). Therefore, it is critical to protect it from pollution and ensure its sustainability (Alloway, 1995; Nriagu, 1988). In the recent years, soil pollution has been accepted as an important environmental issue both in developed, and developing countries, mainly because of the effects of soil pollution on changes in the land use patterns (Andreu and Boluda, 1995; Chen et al., 2009). Among numerous soil pollutants, heavy metals (HMs) are especially dangerous due to their high toxicity and persistence in the environment. Two primary sources have been identified for HMs pollution; natural or geological inputs including rock weathering and thermal springs, and anthropogenic sources including metalliferous mining and associated industries, vehicle exhaust emissions and agronomic practices (Gallego et al., 2002; Micó et al., 2006; Rodríguez Martín et al., 2007; Zhang et al., 1999). A large proportion of toxic concentrations of HMs is introduced from farming practices, such as organic and mineral fertilization, application of pesticides, and irrigation water. (Rodríguez Martín et al., 2007; Romic and Romic, 2003). Heavy metals can be transferred from the soil to other ecosystem compartments such as groundwater and crops. Hence, they can affect human health by polluting water supply and food chain (De Temmerman et al., 2003; Sa´nchez-Camazano et al., 1998). The study of the Concentration, spatial distribution and source identification of HMs in agricultural soils is very important in order to identify the areas of pollution and assess the potential sources of pollutants (Li and Feng, 2012). Usually, the identification of pollutant sources is conducted with the aid of multivariate statistical analyses, such as correlation analysis, Factor analysis etc. (Einax et al., 1997; Han et al., 2006; Li and Feng, 2012; Luo et al., 2007; Tahri et al., 2005). On the other hand, many environmental pollution indices are typically used to assess enrichment of HMs and to describe soil quality in the environment (Abrahim and Parker, 2008; Din, 1992; Hakanson, 1980; Jung, 2001; Muller, 1969; Nishida et al., 1982; Praveena et al., 2007; Shin and Lam, 2001; Tomlinson et al., 1980). Pollution indices are also powerful tools to distinguish the source or origin of heavy metal contaminations (Caiero et al., 2005).

The study area with a surface of approximately 7850 km^2 is located in the center of Iran (Fig. 1). In the last two decades, this region has undergone a rapid transition from a traditionally agriculture-based economy, to an increasingly industrial/mining-based economy. Industrial and

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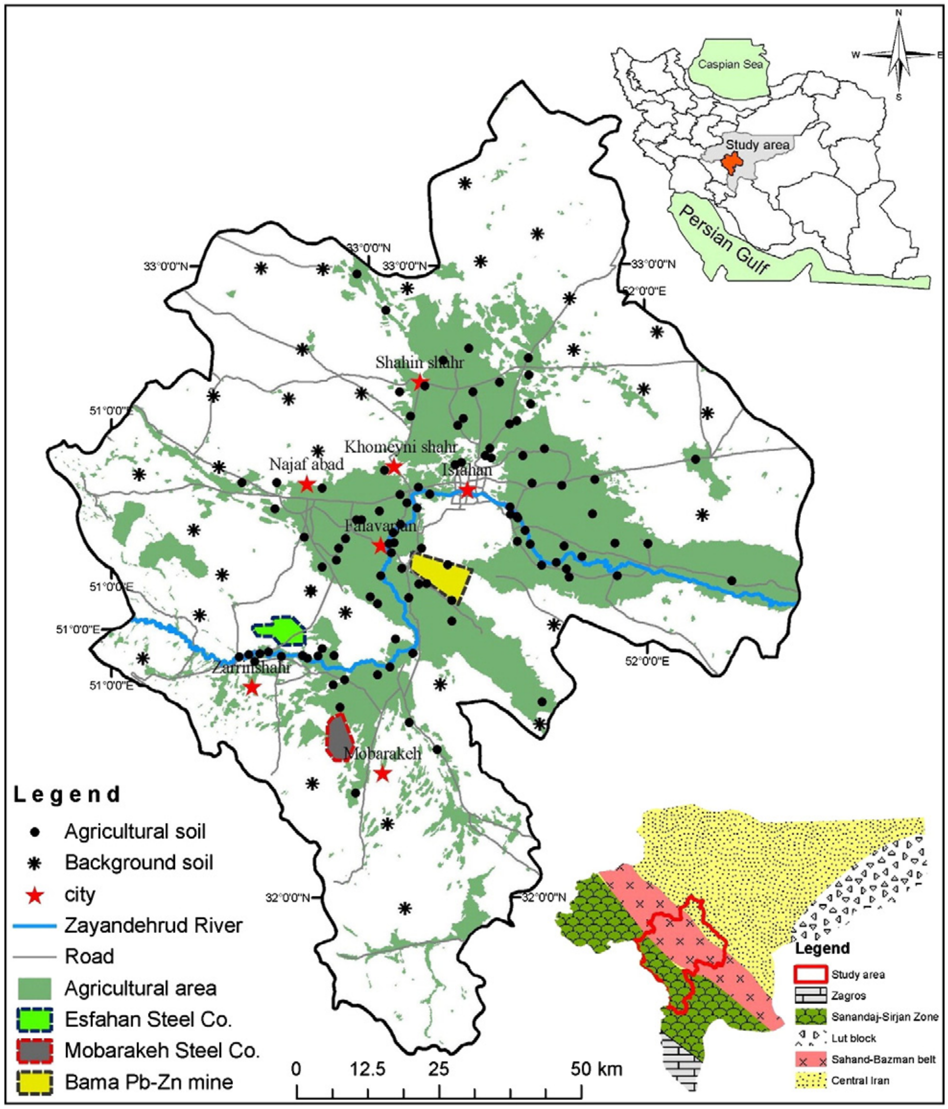

Fig. 1. Location of agricultural soils and sampling sites.

mining operations accompanied by expansion of the population along with pollutant emission have considerably increased waste and wastewater discharges in the study area. Once heavy metals enter and accumulate in agricultural soil through irrigation and atmospheric deposition, the risk of contamination of the food chain is dramatically enhanced. The aims of this research are: (1) to evaluate heavy metal contents of agricultural and background soils in the study area; (2) establish geochemical background levels for heavy metals; (3) to assess the degree of heavy metal contamination and their geochemical association in the soils; and (4) to investigate potential sources of heavy metal contamination in the region.

2. Materials and methods

2.1. Study area

The study are is located between 51° 8′ and 52° 12′ E longitude and 32° 11′ and 33° 6′ N latitude, with a total surface area of 7850 km^2 (including 9 counties) and mean altitude of 1643 m.a.s.l. west of Isfahan province (Fig. 1). According to the Isfahan meteorological office internal reports, the climate of the study area is arid to semi-arid. The mean monthly temperature reaches its maximum (28.8 °C) during July–August and its minimum (3.3 °C) in January. Mean annual temperature is 10.8 °C. Also, rainfall is seasonal and 80% of rainfall occurs between January and April. The mean annual rainfall is about 70 mm. The study area is a part of Zayandehrud River basin, an important agricultural area (still with traditional agricultural practices) in central Iran (200000 ha of intensively cultivated land). Cereals comprise the largest proportion of this cultivated area (60 %). Fruit production (7%) is also locally important. The area, with an approximate population of 3.6 million, is also intensively industrialized. Nearly 4000 small factories are active in the region. These factories are mostly small metallic and non-metallic (75%), textile (8.5%), chemical (7.5%), food (5%), electronic (3%) and pharmaceutical (1%) plants. Large scale industry including petrochemical and oil refinery industries, chemical industry, cement industry, power generation plants, iron and steel industry are mainly concentrated on the banks of Zayandehrud River (Fig. 1). Sewage discharge and emission of exhaust gas, as well as industrial emissions and mining dusts can have negative repercussions on soils, and negative effects on the quality of agricultural products (Gil et al., 2010; Rodrı́guez et al., 2009). Geologically, the study area includes parts of three sedimentary-structural zones introduced by Nabavi (1976), namely Sahand-Bazman volcano-magmatic belt, Sanandaj-Sirjan metamorphic belt, and Central Iran zone. The Quaternary unconsolidated alluvial sediments are widely distributed in the study area (Fig. 1). Lithologically, the main exposed rocks are Mesozoic sedimentary rocks (limestone,