Journal of Geochemical Exploration 152 (2015) 91–109

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

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

Geochemical assessment of steel smelter-impacted urban soils, Ahvaz, Iran

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ARTICLE INFO

Article history:
Received 3 July 2014
Accepted 11 February 2015
Available online 18 February 2015

Keywords:
Urban soil
Metals
Steel smelter
Iran

ABSTRACT

Geochemical study of urban soils is a challenging work due to high diversity of urban areas and multiple influences of anthropogenic sources on the soil geochemical composition. In the present study, a soil geochemical survey has been performed to determine the spatial distribution and possible sources of metals in the area around the Iran National Steel Industrial Group (INSIG). Concentrations of metals (Cr, Ni, Mn, Zn, Cu, Pb, V, Co and Fe) were determined in 63 topsoil (0–20 cm) and 46 subsoil (40–50 cm) samples. In addition, the pH, soil organic carbon (SOC), cation exchange capacity (CEC), soil grain sizes and $CaCO_3$ were measured for each sample. The mean concentrations of Cr, Ni, Mn, Zn, Cu, Pb, V and Co in the topsoils were 556 mg/kg, 261 mg/kg, 2204 mg/kg, 1716 mg/kg, 157/kg, 122 mg/kg, 177 mg/kg and 41 mg/kg, respectively. This study is based on comparisons of statistical parameters, the spatial distribution of studied elements and the results of hierarchical cluster analysis (HCA) and principal component analysis (PCA). Four natural geochemical associations and one anthropogenic geochemical association were identified for the topsoil layer. Natural geochemical associations (sand, silt and CEC), (Cr, Ni and V), (Co and clay) and (pH) are mainly influenced by geogenic/pedogenic factors, while anthropogenic association (Mn, Zn, Cu, Pb, Fe, SOC and $CaCO_3$) is related to anthropogenic activities in the study area. The principal component analysis of the subsoil data set revealed four main components: the "anthropogenic specific" association of (Zn, Cu, Pb, Fe, SOC and $CaCO_3$) and three "natural specific" associations of (pH, sand, silt and CEC), (Cr, Ni, V and Co) and (Mn and clay). A distinct anomaly of anthropogenically introduced metals was found in soils closer to the steel smelter in the N–SE axes of the study area. The results of HCA and correlation analyses for the data sets of two soil layers suggested that chelated elements (Zn, Cu, Pb and Fe) by soil organic fraction were transported down to the subsurface layer (40–50 cm). According to the Canadian Soil Quality Guidelines, Cr, Ni, Mn, Zn and Cu were the primary critical metals in the both soil layers. This study may provide decision makers with the useful information for management practices to protect human health.

1. Introduction

Urban soil pollution is a consequence of rapid urbanization and development of industries in major cities around the world. In recent years, urban soil geochemistry has gained increasing attention due to the accumulation of toxic elements (Ajmone-Marsan et al., 2008; Alijagić and Šajn, 2011; Alloway, 1995; Argyraki and Kelepertzis, 2014; Dao et al., 2010; Nyarko et al., 2006; Šajn and Gosar, 2014; Stafilov et al., 2010). Because of the heterogeneity and continuous changing of urban landscapes, it is essential to identify the distribution of potentially harmful elements and distinguish their natural sources from anthropogenic ones. Mining activities and metal smelting are the main sources of metals entering into the environment (El Khalil et al., 2008; Kabala and Singh, 2001; Rodríguez et al., 2009).

Contamination of soil occurs mainly in industrial regions and within major settlements where factories, motor vehicles and municipal wastes are most important sources of trace metals (Kabata-Pendias and Pendias, 2001). High concentrations of metals such as Cd, Cu, Hg, Ni, Cr, Pb and Zn and metalloids (As and Sb) have been found in soils around smelters in different countries (Alijagić and Šajn, 2011; Borgna et al., 2009; Li et al., 2011; Liu et al., 2013; Šajn et al., 2013; Stafilov et al., 2010). There is a long history of smelting and metallurgical activities in Ahvaz. The first factory for producing all kinds of steel bars and plain bars (embossed and angles) was established in 1963. During the past years some plants like beam rolling mill, steel making plant and machinery plant were added to this complex, which is known as the Iran National Steel Industrial Group (INSIG). The annual capacity of the complex is 1,435,000 t of steel products. INSIG provides a large part of the country needs and is one of the exporters of steel products in Iran.

Air-borne stack emissions from different industrial complexes (steel plants, cement factories and oil refineries) are major sources of a

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http://dx.doi.org/10.1016/j.gexplo.2015.02.005
0375-6742/

Table 1
Chemical characteristic of emissions from the INSIG smelter (electric-arc furnace dust).

Dust parameter	Mean ± SD	Dust parameter	Mean ± SD
pH[a]	11.8 ± 0.05	Cu (mg/kg)[a]	26.7 ± 0.4
EC_e (ds/m)[a]	3.94 ± 0.06	Pb (mg/kg)[a]	15.4 ± 0.1
P (%)[a]	1.25 ± 0.1	Cr (mg/kg)[b]	0.12 ± 0.002
K (%)[a]	0.071 ± 0.002	S (%)[b]	0.88 ± 0.2
Ca (%)[a]	8.6 ± 0.2	SiO_2 (%)[b]	2.17 ± 0.1
Mg (%)[a]	2.3 ± 0.1	Al_2O_3 (%)[b]	0.46 ± 0.08
Fe (%)[a]	42.3 ± 1.35	Na_2O (%)[b]	26.23 ± 0.5
Mn (mg/kg)[a]	0.28 ± 0.003		
Zn (mg/kg)[a]	34.3 ± 0.2		

[a] Jalili Seh-Bardan et al., 2013.
[b] Khoda-Bakhsh Nezhad, 2008.

widespread diffusion of various pollutants including metals into Ahvaz urban soils (Afkhami et al., 2013; Fazeli et al., 2009; Hani et al., 2014; Ziaghomi et al., 2013). This affected the spatial variation of metals and geochemical composition of the soils around the industrial sites in Ahvaz. Considering that no soil geochemical study has been carried out in this area; this study was designed and implemented to investigate metal distribution and geochemical patterns of the soils around the INSIG.

The main objectives of this study were: (a) to study of spatial distribution of chemical elements in the topsoil and subsoil, (b) to determination different geochemical associations and possible pollution sources, (c) to determine the spatial contamination in topsoils and subsoils, and (d) to assess the soil pollution indexes in the study area.

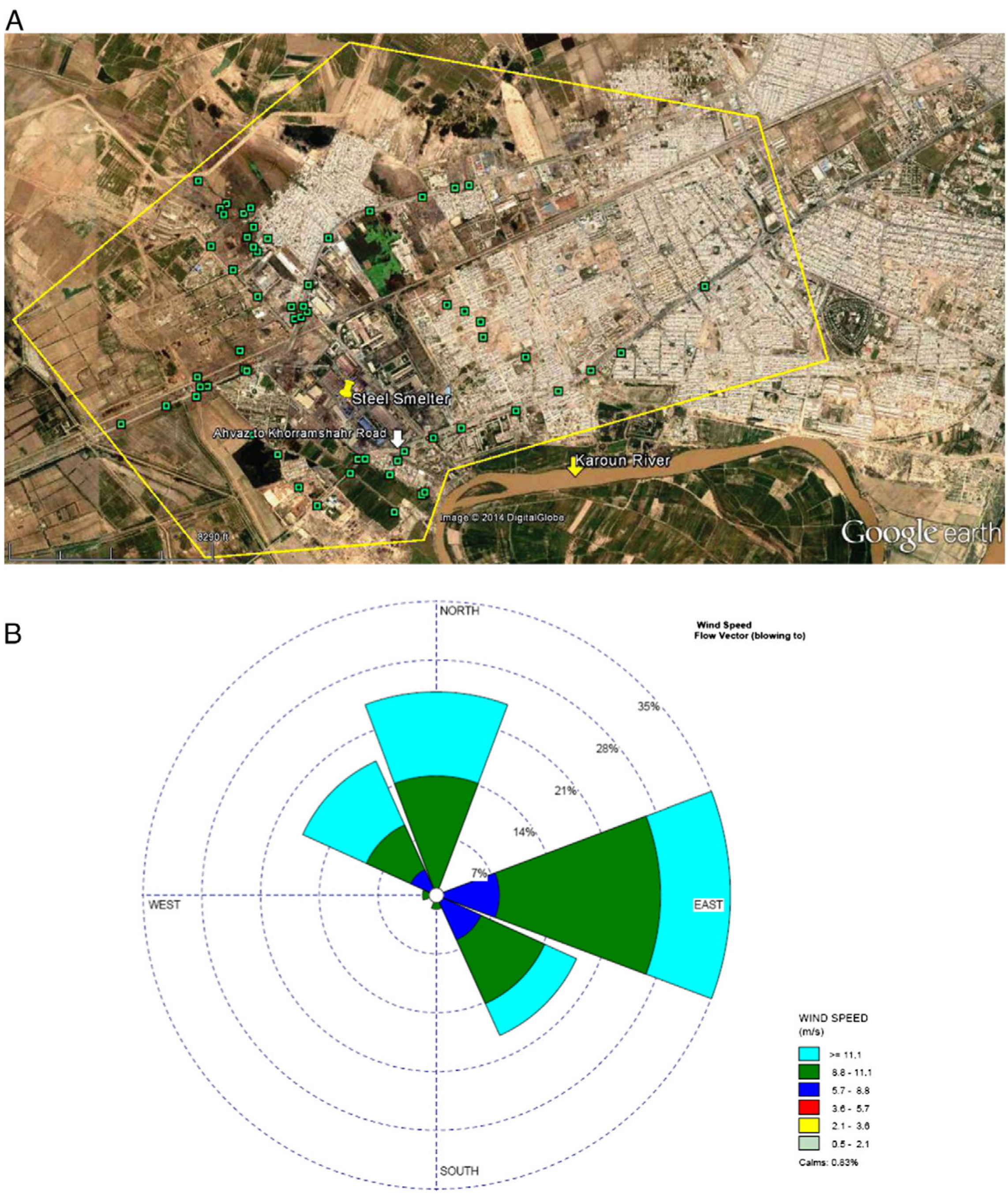

Fig. 1. (A) location of the study area (Google Earth map of the INSIG steel smelter in Ahvaz, with sampling spots — square-pointed). (B) Wind rose plot of the Ahvaz city.