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Total concentration, speciation and mobility of potentially toxic elements in soils around a mining area in central Iran

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ABSTRACT

The current study was designed to investigate the extent and severity of contamination as well as the fractionation of potentially toxic elements (As, Cd, Cr, Cu, Pb, Zn, Ni) in minesoils and agricultural soils around a Pb–Zn mine in central Iran. For this purpose, 20 agricultural soils and eight minesoils were geochemically characterized. Results showed that minesoils contained elevated concentrations of As (12.9–254 mg kg^{-1}), Cd (1.2–55.1 mg kg^{-1}), Pb (137–6239 mg kg^{-1}) and Zn (516–48,889 mg kg^{-1}). The agricultural soils were also polluted by As (5.5–57.1 mg kg^{-1}), Cd (0.2–8.5 mg kg^{-1}), Pb (22–3451 mg kg^{-1}) and Zn (94–9907 mg kg^{-1}). The highest recorded concentrations for these elements were in soils influenced directly by tailing ponds. Chromium, Cu and Ni content in agricultural soils (with average value of 74.1, 34.6 and 50.7 mg kg^{-1}, respectively) were slightly higher than the minesoils (with average value of 54.5, 33.1 and 43.4 mg kg^{-1}, respectively). Sequential extraction data indicated that there were some differences between the speciation of PTEs in soil samples. In the agricultural soils, Zn and Cd were mainly associated with carbonate bound fraction, As and Pb with reducible fraction, Cu with oxidisable fraction and Cr and Ni with residual phase. With respect to mobility factor values, Zn and Cd in the agricultural soils have been found to be the most mobile while As mobility is negligible. Also, the mobility factor of As, Cd and Pb in agricultural soils adjoining tailing ponds was high. In minesoil sample Cd was most abundant in the carbonate form, whereas other studied elements were mainly present in the reducible and residual fractions; therefore, despite the high total concentrations of As, Pb and Zn in the minesoils, the environmental risk of these elements was low. Based on the obtained data, a portion of Cu, Cr and Ni input was from agricultural activities.

1. Introduction

Mining activity is considered as one of the most hazardous anthropogenic activities in the world (Acosta et al., 2011) and its disruptive effects on the environment have been known for decades. Generally, mining activities are associated with waste production and the disposal of mine wastes often produces more environmental problems than the mining operations themselves (Fernandez-Caliani et al., 2009). Mining and processing of Pb–Zn ores lead to the production of large amounts of waste rocks and tailings. The disposal of tailings is a major environmental issue that has become more serious with the increasing exploration for metals and the exploitation of lower grade mineral deposits (Ozkan and Ipekoglu, 2002). The environmental impacts of tailing ponds generally result from their low pH, low organic matter, scarce or nil vegetation and large amounts of potentially toxic elements (PTEs) (Acosta et al., 2011; Favas et al., 2011). PTEs may be transferred from tailing ponds to nearby soils by acid mine drainage and/or atmospheric deposition of wind-blown dust; thus, mine tailings are one of the most important sources of soil pollution (Siegel, 2002; Ferreira da Silva et al., 2004; Boularbah et al., 2006). In recent years, pollution of soil by PTEs in areas adjacent to mine sites has been reported in many countries (Cui and Xin, 2011).

Total concentrations of PTEs provide no information on their likely environmental impacts. Furthermore, the speciation studies could be used to determine the mobility and availability of PTEs. Using the sequential extraction procedure, by which the relative contribution of main soil phases in the retention of different

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elements is determined, it is feasible to predict manner of occurrence, mobility, solubility, bioavailability, toxicity and transport as well as the origin of PTEs (Lasheen and Ammar, 2009; Favas et al., 2011; Nannoni et al., 2011).

Irankuh mining area in central Iran contains 23 million tons of lead–zinc ore (7.4% Pb and 2.4% Zn). With an annual extraction rate of 358,000 tons of ore, this site is one of the major Pb–Zn producers in Iran. Zinc and Pb concentrates are produced by flotation processes. These processes result in the production of considerable volumes of tailings, which are disposed of in large tailing ponds. Agricultural activities in Irankuh area are extensive and the mine's tailing ponds usually neighbor the farms. The main crops are seasonal including vegetables, barley, and wheat. Potatoes and alfalfa are also cultivated. These products are either locally consumed or marketed in Isfahan, a mega city located nearby. Manure is widely used as fertilizer. The farms are mainly irrigated by local groundwater resources. The present study aims to investigate the mobility and bioavailability of PTEs (As, Cr, Cu, Cd, Pb, Zn, Ni) in soils around this mining zone.

1.1. Site description

Irankuh zinc and lead deposits are located along the Irankuh mountain range, 25 km southwest of Isfahan in central west Iran (Fig. 1). The climate of the area is semiarid with annual mean temperature of 14.5 °C. Mean annual precipitation is 140 mm, with rain events falling mostly in autumn and spring. In contrast to little rainfall, the mean evaporation rate in the area is 1705.6 mm $year^{-1}$. Two prevailing wind directions are W and SW. Incidence of wind erosion process negatively affects soil in the surrounding areas.

1.2. Geological setting

Geologically, the mine site is located in the Sanandaj–Sirjan structural zone, and is one of the Pb–Zn deposits on the Isfahan–Malayer mineralization belt. The oldest rocks of this area include green-brown to dark grey shales of Jurassic age. These shales are probably the source rocks for Pb–Zn mineralization (Ghazban et al., 1994). Cretaceous carbonate rocks whose thickness is approximately 800 m overly unconformably Jurassic shales. Stratiform lead and zinc mineralization has occurred in folded Cretaceous carbonate sequence. The main ore and gangue minerals in this mineralization zone include sphalerite (ZnS), galena (PbS), pyrite and marcasite (FeS_2), chalcopyrite ($FeCuS_2$), cerussite ($PbCO_3$), hemimorphite ($Zn_4(Si_2O_7)(OH)_2{\cdot}H_2O$), smithzonite ($ZnCO_3$), zincite (ZnO), malachite ($Cu_2CO_3(OH)_2$), hematite (Fe_2O_3), limonite and goethite ($Fe_2O_3{\cdot}H_2O$), barite ($BaSO_4$), gypsum ($CaSO_4$), dolomite ($CaMg(CO_3)$) and quartz (SiO_2). Thus, a variety of metals and metalloids (e.g. As, Sb, Cd, Cu) are present as minor elements in the ores.

2. Materials and methods

2.1. Sampling and sample preparation

Fig. 1 displays the location of the sampling points. A total of 28 surface soil samples were collected down to 10–20 cm from zero depth. Twenty samples were collected form soils considered as agricultural soils (contiguous soils). Eight samples

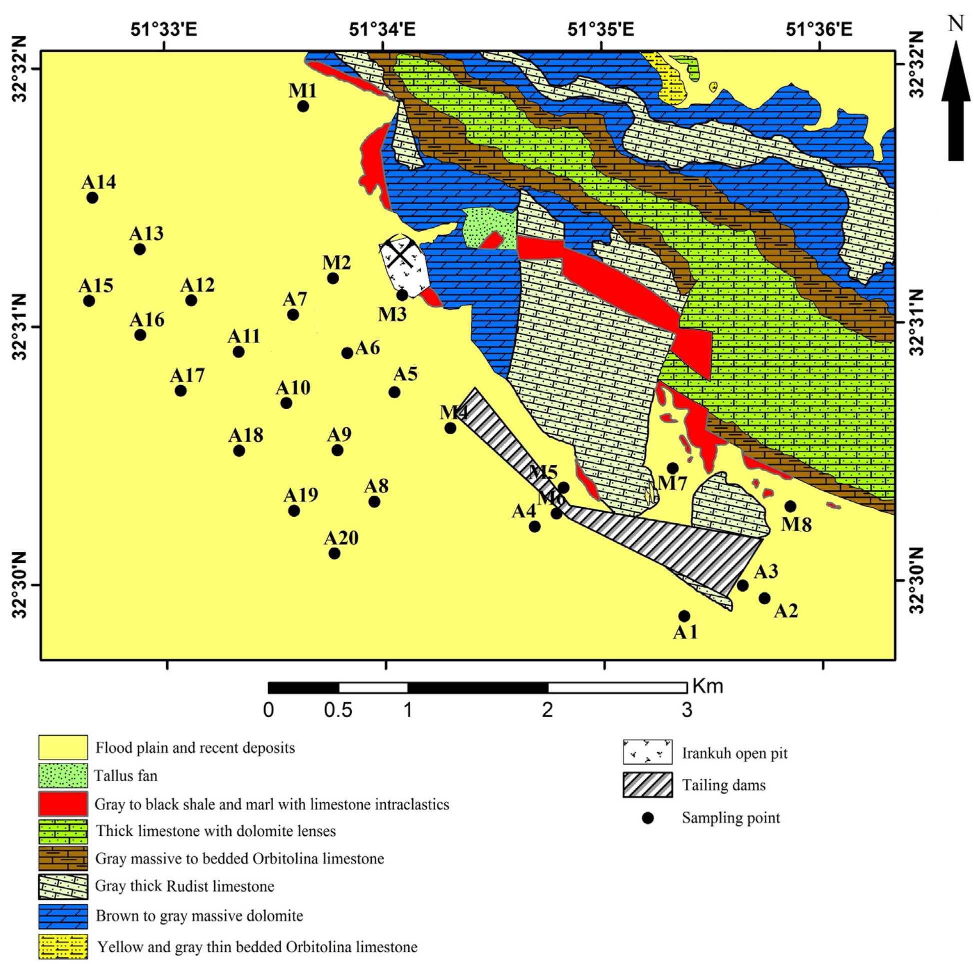

Fig. 1. Geological map of the Irankuh district and location of the sampling sites.