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Assessment of heavy metal pollution in surficial soils surrounding Zinc Industrial Complex in Zanjan-Iran

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Abstract

In this study the Zinc Industrial Complex located near the city of Zanjan-Iran was selected for detailed study. The objective of the study was to assess the extent and severity of heavy metal contamination of topsoils in this area. We examined the present degree and spatial distribution of heavy metal concentrations in 15 topsoil samples in the Zinc Industrial Complex in Zanjan. The soils were digested with aqua regia for heavy metal analysis. Pb, Zn and Cd concentrations in the topsoil exhibited anthropogenic increased values. The major sources for the heavy metal contamination in studied area are most possibly emissions from zinc industry. These emissions transported by air and sewage water and industrial sewage effluents have been considered to be responsible for the increased heavy metal concentrations found in the soils of the central studied area. Pb, Zn and Cd concentrations up to 63, 3066, 18.5 mg kg-1 was found in most pollutant area. Concerning the health risk of the population bioavailability and mobility of heavy metals seems to be of major importance, based on the soil properties found in the study area. Heavy metal contamination of soil is widespread and there is a risk of transfer of toxic and available metals to humans, animals, and agricultural crops. If they are phytoavailable, some toxic metals are potentially accumulated in some plants and may pose a threat to humans and grazing animals.

Keywords: Heavy metals; Contamination; Tailings; Zanjan Province; Iran

1. Introduction

Angoran area of Zanjan province located in North West of Iran has a large metalliferous site and has been considered as a traditional mining region since antiquity. There are still large reserves of lead (Pb) and zinc (Zn) in the area. Both mines and smelting units within the province present a risk of contamination of soils, plants, surface and groundwater by dissemination of the particles carrying metals by wind action and/or by runoff from the tailings. Heavy metal contamination in Zanjan province has also been previously reported in the vicinity of Lead and Zinc mining and smelting sites [1-5].

Heavy metal contamination of soils is widespread and there is a risk of transfer of toxic and available metals to humans, animals, and agricultural crops. In fact, heavy metals have a significant toxicity for humans, animals, microorganisms and plants [6, 7]. Heavy metals are natural constituents of the Earth crust. A number of these

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elements are biologically essential at trace levels present in natural water, air, dusts, soils and sediments, and play an important role in human life [8, 9]. Anthropogenic activities such as mining and smelting of metal ores is one of the main sources of heavy metals in soils and is responsible for increased prevalence and occurrence of heavy metal contamination at the Earth's surface. Opencast mining activities have a serious environmental impact on soils and water streams, having generated millions of tons of sulfide-rich tailings [10]. If these metals are phytoavailable, some toxic metals are potentially accumulated in some plants and may pose a threat to humans and grazing animals. Some soils contain high concentrations of metals from geochemical sources [11], while others are contaminated by metals from anthropogenic activity such as phosphate fertilizer application, industrial wastewater effluents derived from the mining process, and wastewater sludge's [12,13].

Assessment of soil contamination with heavy metals can be determined by estimating the bioavailable fraction of toxic metals. Metal mobility in soils has generally been assessed using a chemical approach based upon selective extractions [14, 15].

The objectives of this study were to evaluate heavy metal content and toxicity in different soils and tailings from Zinc Specialized Industrial Town located in the south of Zanjan city, the capital of Zanjan province, situated in North West of Iran and also to carry out a preliminary assessment of the environmental risk associated with heavy metal pollution in soils from the studied area. Here the possibilities of spreading pollution to the nearby areas, especially along the direction of the prevailing winds, through dust blow-offs poses a potential threat for the local communities.

2. Study Site

The research was conducted in Zinc Industrial Complex (36° 66′ N, 48° 48′ E). The Zinc Specialized Industrial Complex was established in 1996, with a current consumption of about one million tons of raw ore and a production of 0.19 million tons of Zn per year. Soil samples were collected from the site during second week of September 2009 in the study area (Fig. 1).

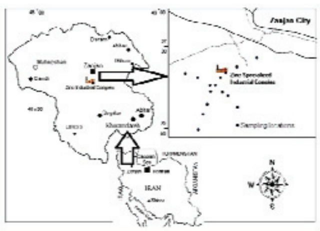

Fig.1. Location map of the studied area indicating sampling points

3. Materials and methods

A total of 15 soil samples were collected from of the industrial complex surrounding area. Another two samples of references were also collected from an area 10 kilometres away from the industrial complex. Soil samples were collected from the surface of the soil (0-20 cm deep) and preserved by using the methods of soil analysis [16]. The region was stratified into regularized grid cells of 0.1 *0.1 km, within each a sampling location was chosen randomly. From each sampling points, five Soil samples were gathered and mixed properly to obtain a composite sample mixture. The soil sampling spots were cleared of debris before sampling. Each composite soil samples were placed in cellophane bags [17], labelled and was taken to the laboratory for pre-treatment and analysis. The sampling tools were washed with soap and rinsed with distilled water after each sampling.

In the laboratory, bulk soil samples were spread on trays and were air dried at ambient conditions for two weeks. The samples were then grounded by mortar and pestle, sieved through a 2 mm mesh, and oven-dried at 50◦ C for about 48 hours. The samples were then stored in polyethylene bags and re-homogenized before being used. The soil samples were digested using the 11466, ISO standard method (the aqua regia digestion method) [ISO 11466]. 3 g of soil was placed in a 100 ml round bottom flask with 21 ml of concentrated HCl (35%) and 7 ml concentrated HNO3

(65%). The solution was kept at room temperature overnight before a water condenser was attached and the solution heated to boiling for 2 hours. 25 ml of water was added down the condenser before filtration of the mixture through using a Whatman (No. 42) filter. The filtered residue was rinsed twice with 5ml of water and the solution was made up to 100ml. All solutions were prepared with Milli-Q deionised water. The above procedure was also used to obtain a blank and control samples and all samples were blank-corrected Concentrations of Pb, Zn, and Cd in the digested samples was determined using Atomic absorption spectrometry (Varian, Germany). The pH and EC (solid: distilled water=1:5) of the soil samples were also measured by with pH and EC meters (Metrohm, Germany).

4. Data processing

The relationships between the individual elements and between some soil parameters and the elements have been assessed. Maps of isolevels of heavy metal contents have been produced as a first approach to know their spatial distribution in the studied soils. Geographical information systems are increasingly being used for producing thematic maps [18-20]. A raster-based GIS has been used to integrate physiographic, lithologic and soil information and to produce a number of combinations of output data that resulted in several thematic maps. Thus, the spatial distribution of heavy metals in the soils in and around the industrial complex has been mapped by geostatistical interpolation. Two-dimensional ordinary block kriging as a most advantageous interpolation technique was applied to produce regular grids.

The present database includes topography layer map, soils layer, mean annual precipitation (mm), soil profile descriptions and associated data. The digitized topography of the studied area was used to build up a digital elevation model of the area with Surfer, a program linked to IDRISI GIS. Statistical analyses were performed with SPSS for Windows 10.0.5 and Microsoft Office Excel 2007.

5. Results and Discussion

Table1 illustrates the metal concentrations in the studied area. Comparing the results with standards range (table2), shows that the concentrations of heavy metals in this area are higher than standard. However the heavy metal concentration in our study is lower than other countries standard ranges.

Table1 Total metal concentrations in the topsoil of Industrial Complex in Zanjan-Iran.

Site	pH	EC(μs.cm^{-1})	Total metal (mg.kg^{-1})		
			Pb	Zn	Cd
1	7.77	3439.52	210	3066.6	3.85
2	7.51	12886.04	630	1560	18.5
3	8.20	15352.68	218.93	890	12.6
4	7.68	3144.33	446.86	881	8.2
5	7.86	3608.08	62	496.3	0.56
6	7.93	5117.85	46.16	340	1.16
7	7.92	30121.7	99.3	256.56	0.28
8	7.91	1160.08	15	211.56	0.43
9	7.74	5117.85	10.23	171.93	0.16
10	7.91	867.78	4.1	186.66	0.16
11	7.94	395.85	11.06	156.2	0.16
12	7.77	10536.02	25.73	295.33	3.33
13	7.91	867.78	14. 6	281	0.94
14	7.65	957.2	9.5	146.4	1.1
15	7.82	859.4	10.2	153.4	0.45
Avg.	7.83	6295.48	128.51	606.20	3.46
Max.	8.20	30121.70	630.00	3066.20	18.50
Min.	7.51	395.85	4.10	146.40	0.16
STDEV	0.16	8094.83	191.07	786.78	5.47

Table 2 Maximum level of heavy metal concentrations in different countries

Heavy Metal	German	England	Japan	Canada	Normal Range
Pb (mg kg^{-1})	500	100	400	200	0.1-20
Zn	300	300	250	400	3-50
Cd	2	3	-	8	0.1-1

Table3 Range, mean ± standard deviation (S.D.) and median characteristic of topsoil

	Mean (S.E)	Median	Range	
			Min.	Max.
pH	7.83(0.16)	7.86	7.51	8.20
EC	6295.47(8094.82)	3439.52	395.85	30121.70
Total metal concentration (mg kg^{-1})				
Pb	128.50(191.07)	35.95	4.10	63.00
Zn	606.20(786.78)	281.00	146.41	3066.6
Cd	3.46(5.47)	0.94	0.16	18.50

Mean, standard error (S.E.), median and range (n = 15).

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