Journal of Advances in Environmental Health Research

Heavy metal contamination in soil and some medicinal plant species in Ahangaran lead-zinc mine, Iran

Mehrdad Cheraghi[1], Seyed-Meysam Mosavinia[1], Bahareh Lorestani[1]

1 Department of the Environment, School of Basic Sciences, Hamadan Branch, Islamic Azad University, Hamadan, Iran

Original Article

Abstract

Ahangaran lead-zinc mining area located in the west part of Iran is a mountainous region. In this study, medical plants and soils from 3 different sites in this area were collected in spring 2012. Soil and medical plants were analyzed for heavy metals [lead (Pb), zinc (Zn), cadmium (Cd) and copper (Cu)] concentrations using inductively coupled plasma (ICP) optical emission spectrometer (Varian 710-Es) and the physical properties of soils [(pH) and electrical conductivity (EC)] were measured. Soil and medical plants of the mineralized zone and surrounding areas have higher heavy metal contamination ($P < 0.05$) as compared to the reference site, which can be attributed to the dispersion of metals due to mining. This high heavy metal contamination may pose potential threats to local medical plants and soil of Ahangaran region. Furthermore, the concentrations of Pb and Cd in soil surrounding the mine were higher than the US environmental protection agency (USEPA) standard, and the concentration of Pb in medical plant species surrounding the mine was higher than the world health organization (WHO) standard for edible plants ($P < 0.05$).

KEYWORDS: Mine, Medical Plant, Heavy Metals, Contamination

Date of submission: 18 Mar 2013, ***Date of acceptance:*** 22 May 2013

Citation: Cheraghi M, Mosavinia SM, Lorestani B. **Heavy metal contamination in soil and some medicinal plant species in Ahangaran lead-zinc mine.** J Adv Environ Health Res 2013; 1(1): 29-34.

Introduction

The pollution of soil ecosystem with lead (Pb), zinc (Zn), cadmium (Cd) and copper (Cu), are considered as global environmental problem. These metals have both natural resources such as weathering/erosion of parent rocks and ores deposits, and anthropogenic resources such as mining, smelting, industrial emission, waste water irrigation and application of fertilizers have all contributed to elevated concentrations of heavy metals in the environment.[1-4]

Mining activities have a serious environmental impact on soils and plants. Moreover, there are may be safety risks for people working in mines or for those living close by the risk of habitat destruction.[5] The negative impact of these mining activities on the surroundings is mainly due to the presence of high volumes of tailings that usually have adverse conditions to natural plants growing on it.[6] Some plant species can grow in these severe conditions. High concentration of heavy metals in medical plants can cause oxidative stress and stomata resistance.[7,8] It can also affect photosynthesis and chlorophyll florescence processes.[9] Pb, Zn, Cd and Cu are potentially poisonous for medical plants i.e. phytotoxicity results in chlorosis, weak plants growth, and may even be accompanied by decrease nutrient uptake, disorders in plant metabolism, and a reduced ability to fixate molecular nitrogen.[10]

Moreover, Cu can inhibit photosynthesis and

Corresponding Author:
Seyed-Meysam Mosavinia
Email: meysam.mosavinia@yahoo.com

reproductive processes; Pb can reduce chlorophyll production, while Zn stimulates the growth of leaves and shoots.[11-13]

The use of plants for medicinal purposes extends long before recorded history. Mankind has had no choice but to use medicinal plants in all ages. Although chemical medications have developed in the past half century, their harmful side effects have revitalized inclination toward herbal medicine. Iran is one of the countries with the most diversity of medicinal plants due to its climate diversity. There are more than 1200 herbal species, of which 315 species belong to 71 families and 209 genera. This study aimed to investigate the contamination of soil and three medicinal plants growing (Table 1) in Ahangaran Mine site to Pb, Zn, Cu and Cd. and calculation of one sample t-test (BCF).

Materials and Methods

The medical plants and soil samples used in this study were collected from a known metal-contaminated site located in an urban area, called Ahangaran lead-zinc mine of Malayer city, west of Iran (Figure 1). It lies in 34° 11′ 08″ N latitude and 48° 59′ 25″ E longitude. The site has been vacant, with an area of approximately 1,600,000 m^2, and is covered mainly by grasses. Human activities such as mining have contributed to metal concentrations in this site. Selected characteristics of the soil samples collected from this study are shown in table 2.

Samples of soil and plants were collected in spring 2012. In the study area, three native medical plant species were randomly collected from the area surrounding the iron mine. Soil

Table 1. Selected plant species along with their family and local names in the study area

No.	Species scientific name	Abbreviations	Family name	Local name
1	Echinophora platyloba	E. platyloba	Apiaceae	Tighedoragh
2	Achillea millefolium	A.millefolium	Asteraceae	Bomadaran
3	Centaurea cyanus	A. cyanus	Asteraceae	Golegandom

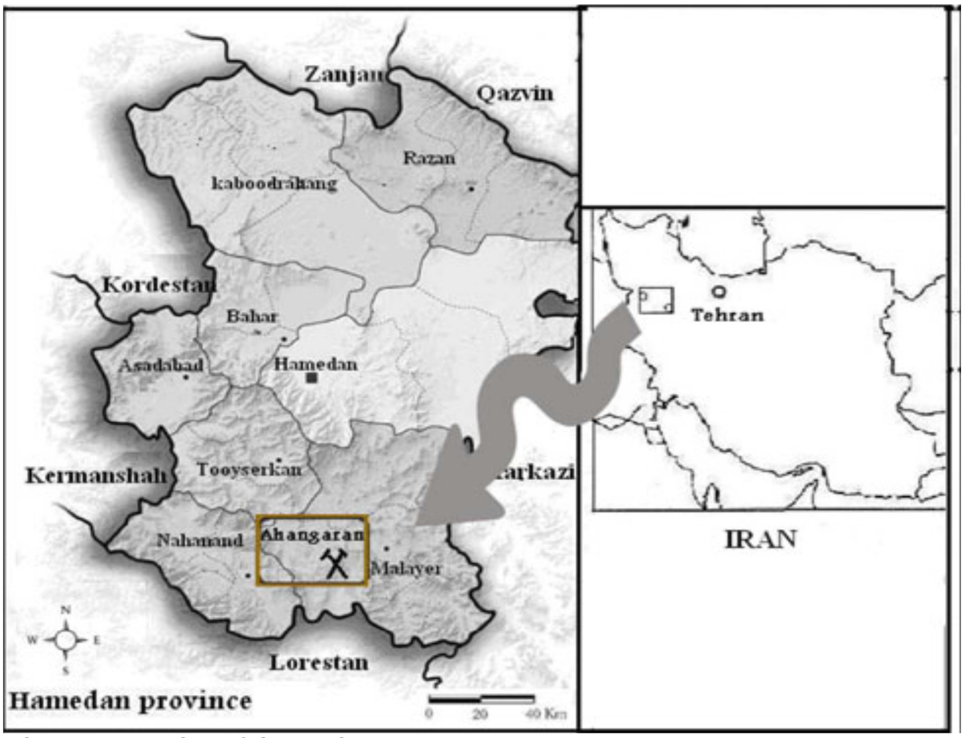

Figure 1. Location of the study area7

Table 2. Soil characteristics of the surrounding area in Ahangaran mine

Site	EC (ds/mm)	pH	TDS (mg/l)	Salinity	Soil texture
Site 1	182.8	7.67	109.5	0.4	loam-sandy
Site 2	328.0	7.85	197.6	0.4	loam-sandy
Site 3	143.2	7.50	168.2	0.4	loam-clay-sand

EC: Electrical conductivity; TDS: Total dissolved solids

sample was collected up to a depth of 30 cm from the base of each uprooted plant. Samples were cleaned from soil and packed in polyethylene bags and properly marked. Unmineralized zone (reference site) soil and plant samples were also collected about 10 km away from the mineralized sites. Herbarium sheet of all different plant species was prepared, identified and taxonomically classified with help of taxonomist in the University of Bu Ali Sina, Hamadan, Iran.

Soil samples were air-dried and passed through a 2 mm sieve before the analysis. Parameters such as pH and electrical conductivity (EC) were determined in a soil i.e. solution ratio 1:5, using a pH meter and an EC meter, respectively, according to the procedure adopted form Das and Maiti.[14] Particle size was determined by the hydrometer method.[15]

For heavy metals determination, soil samples were ground in ball mill to finer than 200 mesh size. 0.5 g of the finely ground soil sample was accurately weighed into Teflon® beaker with cover, 40 ml HF (hydrofluoric acid) and 10 ml conc. Hydrochloric acid (HCl) was added, the covered beaker was heated to 130-140° C; to complete attack, the acid was evaporated then 1:1 HCl was added and the solution was diluted to 100 ml with double-distilled water.[16] Digested soil samples were analyzed for Pb, Zn, Cu, Cd using ICP optical emission spectrometer (Varian 710-Es).

Plant samples were washed with double-distilled water (DDW), oven dried at 70° C and powdered with electric grinder. Accurately, 2.0 g of plant samples were taken in the pyrex beaker and digested with mixture of acids [HNO_3 (nitric acid), $HClO_4$ (perchloric acid)] and aqua regia); and dilute the extract to 50 ml with DDW, according to the digestion method adopted from Ryan.[17] Digested medical plants samples were analyzed for Pb, Zn, Cu, Cd using ICP optical emission spectrometer (Varian 710-Es).

Statistical analyses of experimental data were performed using SPSS for Windows (version 18.0, SPSS Inc., Chicago, IL, USA). Data were tested for goodness of fit to a normal distribution, using a Kolmogorov-Smirnov one-sample test. One sample t-test was used for the comparison of the heavy metals in the soil of the contaminated site to those of the uncontaminated (reference site) and the US environmental protection agency (USEPA) standard for heavy metals in soil.[18] Independent t-test and one sample t-test were used for the comparison of the heavy metals in the medical plants of the contaminated site to those of the uncontaminated (reference site) and the world health organization (WHO) standard for edible plants,[18] respectively.

The ability of plants to tolerate and accumulate heavy metals is useful for phytoextraction and phytostabilization purpose and was measured using bioconcentration factor (BCF) defined as the ratio of metal concentration in plant roots to soils [(metal) root/(metal)] soil.[19]

BCF = metal in whole plant DW (distilled water)/metal in soil DW.

Results and Discussion

Physical and Chemical Properties of the Soil

As shown in table 2, soils in the surrounding area of mine were slightly alkaline, with an average pH of approximately 7.67. The pH conditions were suitable for plant growth. The average of EC, were 218 [deci Siemens (dS/mm)]. Besides, texture of soil was loam-sandy in the site 1 and 2 and loam-clay-sand in the site 3.

Heavy Metals Concentrations in Soil Samples

Table 3 summarizes the heavy metals concentrations in soil samples collected from the contaminated site 1, site 2, site 3 and reference sites and standards. According to table 3, the order of heavy metals concentrations in all the three contaminated sites were Pb > Zn > Cu > Cd.

According to results presented in table 3 and one sample t-test results in table 4, the Pb, Zn, Cu and Cd contents in the soil of the surrounding area of the mine were significantly higher than these metals concentration in the reference site ($P < 0.05$).

As shown in table 3, the concentrations of the studied metals in the soil of the contaminated sites were higher than USEPA standards for heavy metals concentration in soil. Table 4 shows that it was only the Pb and Cd concentrations in the soil of the surrounding area of the mine that was significantly higher than the EPA standards. Rodrigez observed that concentrations of heavy metals in agricultural and ranges soils surrounding the mine were very high[20] and also Ghaderian reported that concentrations of heavy metals in the soils of Sarcheshmeh copper mining area (Iran) were significantly higher than those of non-contaminated soils.[1]

Heavy Metals Concentrations in Medical Plant Samples

Table 5 summarizes the heavy metals concentrations in the medical plants samples, collected from the contaminated site 1, site 2, site 3 and the reference site. According to table 4, the order of heavy metals concentrations in all three medical plants samples was Zn > Pb> Cu > Cd. The metal (Pb, Zn, Cu and Cd) contents in the medical plants samples were higher than metals concentration in the reference site and WHO standards for edible plants.

As shown in table 6, all the studied metals in the contaminated sites were significantly higher than the reference site ($P < 0.05$). Table 6 also illustrated it was only the Pb concentration in the medical plants that was significantly higher than

Table 3. Heavy metals concentrations in soil (mg/kg)

Metals	Soil samples					EPA standard
	Contaminated site				Reference site	
	Site 1	Site 2	Site 3	Average		
Cu	228.4	212.8	208.5	216.4	18.0	200
Zn	691.0	688.4	504.2	628.0	134.0	600
Pb	1754.0	1648.2	2028.0	1810.0	47.0	500
Cd	12.1	12.7	14.4	13.0	0.2	5

EPA: Environmental Protection Agency

Table 4. One sample t-test results for the comparison of the heavy metals in the soil of the contaminated site with those of the uncontaminated (reference) site and Environmental Protection Agency (EPA) standard

Metals	Comparison with the reference		Comparison with EPA standard	
	t	P	t	P
Cu	32.845	0.001	2.740	0.111
Zn	7.986	0.015	0.451	0.696
Pb	15.579	0.004	11.577	0.007
Cd	18.680	0.003	11.711	0.007

EPA: Environmental Protection Agency

Table 5. Heavy metals concentrations in medical plants (mg/kg)

Metals	Echinophora platyloba		Achillea millefolium		Centaurea cyanus		Average for contaminated site	Average for reference site	WHO standard
	Contaminated Site 1	Reference	Contaminated Site 2	Reference	Contaminated Site 3	Reference			
Cu	52.0	25.0	74.8	30.0	50.2	24.0	59.	26.0	40.0
Zn	392.2	38.0	480.0	50.0	403.0	45.0	425.0	44.0	60.0
Pb	102.0	12.0	158.6	16.0	152.6	17.0	138.0	15.0	2.0
Cd	4.6	0.2	4.4	0.3	4.5	0.2	4.4	0.7	0.5

WHO: World Health Organization

Table 6. Independent t-test and one sample t-test results for the comparison of the heavy metals in the medical plants of the contaminated site with those of the reference site and world health organization (WHO) standards for edible plants, respectively

Metals	Comparison with reference		Comparison with WHO standard	
	t	P	t	P
Cu	4.017	0.048	0.327	0.757
Zn	13.665	0.005	2.030	0.098
Pb	6.813	0.020	2.600	0.048
Cd	64.000	< 0.001	1.965	0.108

WHO: World Health Organization

Table 7. Accumulation of Cu, Zn, Pb and Cd in the selected medical plants

Metals	Bioconcentration factor (BCF)		
	Echinophora platyloba	Achillea millefolium	Centaurea cyanus
Cu	0.26	0.36	0.24
Zn	0.65	0.69	0.80
Pb	0.06	0.08	0.07
Cd	0.31	0.29	0.26

Pb concentration in the WHO standard. Del Rio et al. indicated that plants grown around Aznalcollar mine in Spain had so much contain heavy metals such as Pb, Zn, Cu[21] and also increased heavy metals concentrations in soils and plants affected by mining activities have been frequently reported.[22]

Accumulation of Metals in Medical Plants

Bioconcentration factor (BCF) can be used to estimate a plant's potential for phytoremediation purpose. A plant's ability to accumulate metals from soils can be estimated using the BCF, which is defined as the ratio of metal concentration in roots to that in soil. Among the 3 screened plants Achillea millefolium growing at site 2 had the highest BCF for Cu (BCF = 0.36; Table 5), though its total Cu concentration in the plant was < 1000 mg/kg. Among the 3 screened plant, Echinophora platyloba growing at site 1 had the highest BCF for Zn (BCF = 0.65; Table 5), though its total Cd concentration in the plant was < 1000 mg/kg. Moreover, among the 3 screened plants Centaurea cyanus growing at site 3 had the highest BCF for Zn (BCF = 0.8; Table 7).

Conclusion

This paper aimed to investigate the impact of Ahangaran lead-zinc mine on the heavy metal pollution of soils and medical plants species. The obtained results have clearly revealed that the order of Cu, Zn, Pb and Cd concentrations in soil and medical plants in all the three contaminated sites was Pb > Zn > Cu > Cd. The concentrations of Cu, Zn, Pb and Cd in soil samples and medical plants species surrounding the mine were significantly higher than reference site ($P < 0.05$). The Pb and Cd concentrations in the soil samples were significantly higher ($P < 0.05$) as compared to the USEPA standard for soils. In addition, the Pb concentration in the medical plants was higher ($P < 0.05$) as compared to the WHO standard for edible plants.

Conflict of Interests

Authors have no conflict of interests.

References

1. Ghaderian SM, Ghotbi Ravandi AA. Accumulation of copper and other heavy metals by plants growing on Sarcheshmeh copper mining area, Iran. Journal of Geochemical Exploration 2012; 123(0): 25-32.
2. Shah MT, Begum S, Khan S. Pedo and biogeochemical studies of mafic and ultramfic rocks in the Mingora and Kabal areas, Swat, Pakistan. Environmental Earth Sciences 2010; 60(5): 1091-102.
3. Wei B, Yang L. A review of heavy metal contaminations in urban soils, urban road dusts and

agricultural soils from China. Microchemical Journal 2010; 94(2): 99-107.
4. Muhammad S, Shah MT, Khan S. Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan. Microchemical Journal 2011; 98(2): 334-43.
5. Jung MC. Heavy Metal Concentrations in Soils and Factors Affecting Metal Uptake by Plants in the Vicinity of a Korean Cu-W Mine. Sensors 2008; 8(4): 2413-23.
6. Nouri J, Lorestani B, Yousefi N, Khorasani N, Hasani AH, Seif F, et al. Phytoremediation potential of native plants grown in the vicinity of Ahangaran lead-zinc mine (Hamadan, Iran). Environmental Earth Sciences 2011; 62(3): 639-44.
7. Fayiga AO, Ma LQ, Cao X, Rathinasabapathi B. Effects of heavy metals on growth and arsenic accumulation in the arsenic hyperaccumulator Pteris vittata L. Environ Pollut 2004; 132(2): 289-96.
8. Shah BA, Shah AV, Singh RR. Sorption isotherms and kinetics of chromium uptake from wastewater using natural sorbent material. Int J Environ Sci Tech 2009; 6(1): 77-90.
9. Monni S, Uhlig C, Hansen E, Magel E. Ecophysiological responses of Empetrum nigrum to heavy metal pollution. Environ Pollut 2001; 112(2): 121-9.
10. Gardea-Torresdey JL, Peralta-Videa JR, de la Rosa G, Parsons JG. Phytoremediation of heavy metals and study of the metal coordination by X-ray absorption spectroscopy. Coordination Chemistry Reviews 2005; 249(17-18): 1797-810.
11. Guala SD, Vega FA, Covelo EF. The dynamics of heavy metals in plantGÇôsoil interactions. Ecological Modelling 2010; 221(8): 1148-52.
12. Ling T, Guanghua Z, Jun R. Effects of chromium on seed germination, root elongation and coleoptile growth in six pulses. Int J Environ Sci Tech 2009; 6(4): 571-8.
13. Ayari F, Hamdi H, Jedidi N, Gharbi N, Kossai R. Heavy metal distribution in soil and plant in municipal solid waste compost amended plots. Int J Environ Sci Tech 2010; 7(3): 465-72.
14. Das M, Maiti SK. Comparison between availability of heavy metals in dry and wetland tailing of an abandoned copper tailing pond. Environ Monit Assess 2008; 137(1-3): 343-50.
15. Rowell DL. Soil science: methods and applications. New York, NY: Longman Scientific & Technical; 1994.
16. Rashed MN. Monitoring of contaminated toxic and heavy metals, from mine tailings through age accumulation, in soil and some wild plants at Southeast Egypt. J Hazard Mater 2010; 178(1-3): 739-46.
17. Ryan J, Estefan G, Rashid A. Soil and Plant Analysis Laboratory Manual. Aleppo, Syria: ICARDA p. 172; 2001.
18. Mardukh Rohani N. Evolution of heavy metal concentration in compost, soil cover and button mashroom (case study: green house in Kurdistan Province) [MSc Thesis]. Hamadan, Iran: Islamic Azad University, Hamadan Branch; 2012.
19. Yoon J, Cao X, Zhou Q, Ma LQ. Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. Sci Total Environ 2006; 368(2-3): 456-64.
20. Rodriguez L, Ruiz E, Alonso-Azcarate J, Rincon J. Heavy metal distribution and chemical speciation in tailings and soils around a Pb-Zn mine in Spain. J Environ Manage 2009; 90(2): 1106-16.
21. Del RioM, Font R, Almela C, Velez D, Montoro R, De Haro BA. Heavy metals and arsenic uptake by wild vegetation in the Guadiamar river area after the toxic spill of the Aznalcollar mine. J Biotechnol 2002; 98(1): 125-37.
22. De Koe T. Agrostis castellana and agrostis delicatula on heavy metal and arsenic enriched sites in NE Portugal. Sci Total Environ 1994; 145(1-2): 103-9.