Article

Variations in the heavy metal accumulations within the surface soils from the Chitgar industrial area of Tehran

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Abstract

As a result of anthropogenic activities in different parts of the world, the soils are seen to be contaminated by heavy metals. In view of this the influence of an industrial environment on the accumulation of heavy metals in the surface soils of the Chitgar Industrial Area Tehran has been investigated. The total 70 top soils samples (0-15cm) were collected for a period between May 2007 and May 2008 and the heavy metal contents were analyzed by Atomic Absorption Spectrophotometer. The studies with Enrichment Factor indicate that Pb has been enriched to quite great extent while the Normalized Scatter Coefficient values indicate faster enrichment of Cd. While Pb shows accumulation in the past, the Cd accumulation has been quite high during the study period.

Keywords soil pollution; heavy metal enrichment; temporal variation.

1 Introduction

Although the heavy metals occur naturally in the soils having formed by the geological processes (such as alteration and weathering of rock) their enriched concentrations in the soils are regarded as great environmental hazard which is mainly due to the mining activities and the industrial emissions in the urban area. Hence the effects of such increased heavy metal concentrations, especially in the soil environment and consequently on the human health have become a critical topic in the recent past in order to control the soil heavy metal pollution in a sustainable manner. It is needless to say that the industrial activities in the metropolitan cities of the world are responsible for the addition of pollutants through chemical factories and residential activities (point sources) and vehicular traffic (non-point sources) which are the primary sources of soil pollution (Majdi and Persson, 1989; Haktanir et al., 1995). Further the regions in the vicinity of the industrial and urban areas are prone to high levels of toxic metals (Fakoyade and Onianwa, 2002) that are derived from the discharge of poorly treated/untreated effluents to lands.

In recent times the rapid and exponential industrial growth in Iran has caused increased production of waste which is particularly witnessed in Chitgar industrial area located towards west of Tehran City. It has many industries including chemical and pharmaceutical factories and manufacturing unite like batteries, metal alloys, metal plating, plastics, automobiles, glass-work, iron-work etc. in response to industrialization the population of the area has increased leading to consequential increase in vehicular traffic also. Furthermore it is observed that most of these industries directly release their poorly treated and/or untreated effluents into nearby ditches and stream while the solid waste is normally dumped on open land and such disposal practices release the heavy metals into the soils of the study area. As a consequence the Chitgar River, which runs through the industrial area, is seen to carry the industrial effluents for quite a long distance which result in the river and groundwater contamination with the toxic materials. Such toxic material is ultimately discharged into the agricultural lands towards the south of Tehran city as the farmers use such contaminated river and ground water for their agricultural needs. Hence in order to monitor heavy metal pollution in an area, due to the anthropogenic activity, the soil samples represent an excellent media because heavy metals are usually deposited in the topsoil (Govil et al., 2001; Romic and Romic, 2003) and help in knowing the sources of heavy metals and also controlling and optimizing their effects on the human health. The present study reports the role of industrial and urban activities in the heavy metal contamination of the soils in the Chitgar industrial area (Iran) with the objectives:

- To assess the extent of heavy metal pollution influenced by urban and industrial activities.
- To predict the rate of heavy metals pollution in the future if the activities are allowed with the same pace.
- To understand the variations in the behavior of different heavy metal.

2 Methods

2.1 Field methodology

To understand the state of environment of the Chitgar industrial area a detailed field survey was carried out and after having identified possible sources of pollution a part of Chitgar industrial area was selected (Fig. 1). This area is under intense human interference in terms of growing urbanization (Municipal sewage sludge, traffic pollution in particular) and industrialization.

2.2 Selection of sampling site

In the present study stratified regular sampling method was adopted for soil sample collection as in geo-assessment of the variables estimated, the stratified regular sampling is more suitable because this kind of sampling draws homogenous error (Burges and Webster, 1980; Burges et al., 1981). For this purpose the grid map of the study area has been used to know the distribution of heavy metal concentration in the whole region by stratifying the region into a regular-sized grid cells, each grid cell is further divided into many smaller sub-cells. Five sampling points in a grid of 0.5×1km at each sampling station (4 at the corners and one at the centre of the grid) were selected and composite samples consisting of five sub-samples were collected from the top (0 to 15cm) layer of the soil using plastic spatula after removing the debris, rock pieces and physical contaminants. A total of 70 topsoil samples (0-15cm) were collected from each sub-cells. In order to have the background concentration values of the heavy metal elements, three soil samples were collected, each from 100cm below ground level, which are least affected by the anthropogenic activities (Table 1). The samples were placed in the clean polythene bags, which were brought to the laboratory.

Table 1 Natural local background concentration values (mg/kg) of the trace elements of the soils.

Sampling stations	Cr	Co	Cd	Cu	Pb	Ni	Zn
1	9.98	8.89	0.35	9.58	5.2	11.26	11.23
2	11.09	8.09	0.31	9.64	5.17	11.27	11.67
3	10.01	7.05	0.36	9.64	5.14	11.31	11.78
Mean	10.36	8.01	0.34	9.62	5.17	11.28	11.56

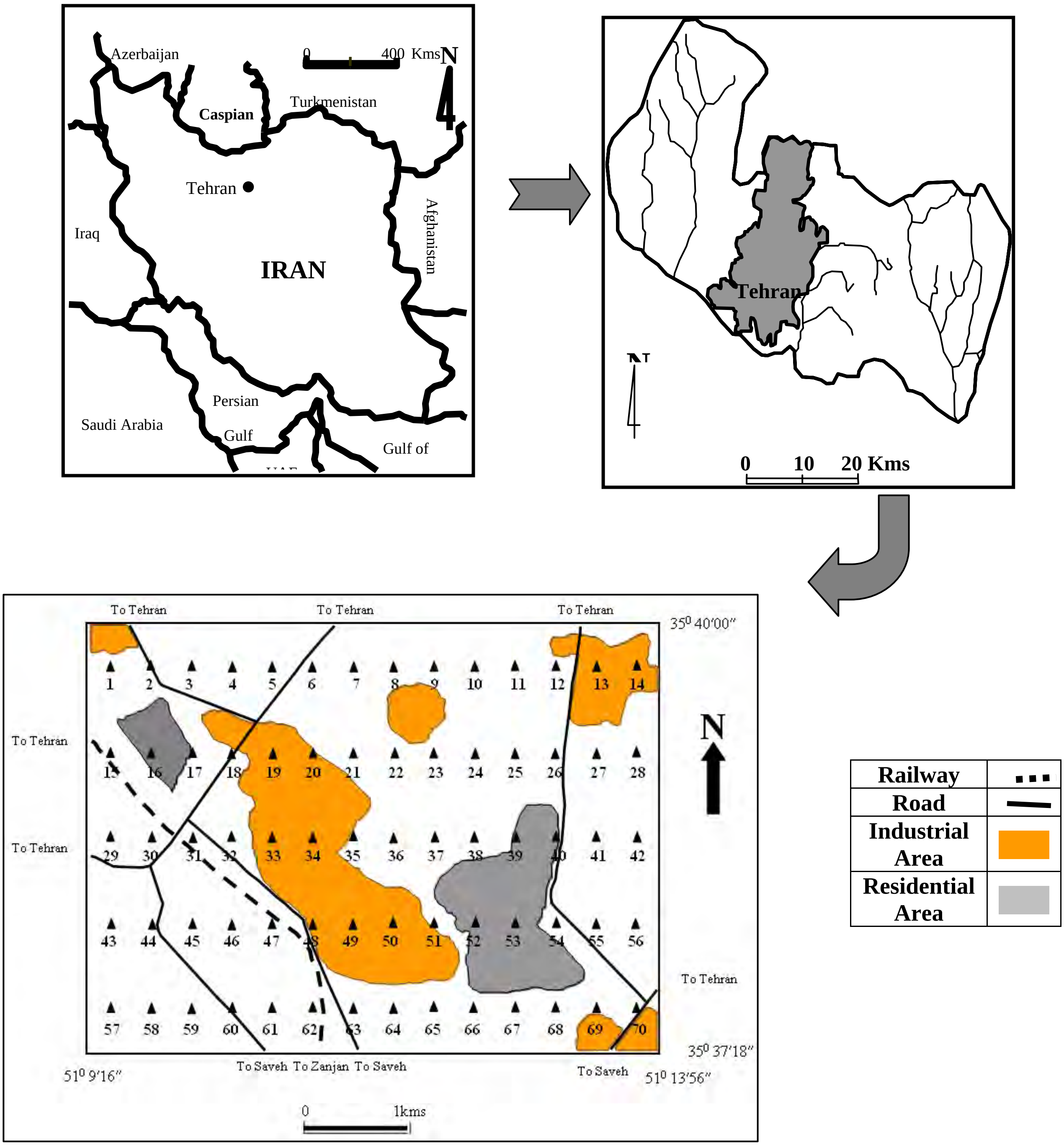

Fig. 1 Location map of the study area with sampling stations.

2.3 Laboratory methodology

The samples were brought to the laboratory where they were air dried and mixed thoroughly to obtain the representative samples. Soon after drying the debris and other objects were hand picked up and the sample were grounds in a mortar to break up the aggregates or lumps, taking care not to break actual soil particles. Soil samples were then passed through a 2mm sieve in order to collect granulometric fraction. Since trace metals are often found mainly in clay and silt fractions of soil and hence the size fraction <63μm is most commonly recommended size. For this purpose the granulometric fraction was added with the dispersing agent and after shaking the sand fraction was separated from the clay and silt with <63μm sieve (wet sieving) and was used to measure the concentration of the heavy metals Cr, Co, Cd, Cu, Pb, Ni and Zn from all the samples collected. For this purpose the clay and silt fraction were digested by acids to get the solution by taking 5g of sample into a 300ml polypropylene wide-mouthed jar and distilled water was added to make a total 200ml. Then it was acidified with 10ml HF, 5ml $HClO_4$, 2.5ml HCl and 2.5ml HNO_3 in order to completely digest the soil. This jar was shaken on an orbital shaker for 16 hours at 200-220 rpm before being filtered through whatman filter paper (No. 42) into acid washed bottles. The solution was stored and heavy metal contents were analyzed by Atomic Absorption Spectrophotometer as per the method recommended by Committee of Soil Standard Methods for Analyses and Measurement (1986). The raw data obtained during the course of laboratory analyses were stored in Microsoft Excel software and further processed to obtain various parameters required for interpretation.

3 Results

The concentrations of heavy metal Cr, Co, Cd, Cu, Pb, Zn and Ni in the soils of Chitgar industrial area were analyzed from the <63 μm soil fractions, collected at 70 sampling stations in three consecutive seasons (May 2007, November 2007 and May 2008). The range of their concentrations found in different sampling stations and seasons are Cr (11.01 - 43.97 mg/kg), Co (8.23 - 16.93 mg/kg), Cd (1.22 - 4.33 mg/kg), Cu (10.42 - 35.57 mg/kg), Pb (27.81 - 68.16 mg/kg), Ni (11.99 - 26.41 mg/kg) and Zn (22.64 - 73.74 mg/kg) and also the mean values for these heavy metals from the surface soils have been calculated to be (25.96±1.01, 12.48±0.20, 2.25±0.06, 22.36±0.82, 49.53±1.31, 14.74±0.27 and 49.37± 1.35mg/kg) respectively at the confidence limits of 95%.

The concentration of the heavy metals at all sampling stations, exhibit an increasing trend over a vary short period of monitoring (May 2007 - May 2008) which is clearly seen from the mean concentrations of the heavy metals over three seasons (Fig. 2). However the mean concentrations of Ni in soils exhibit an increasing trend between May 2007–November 2007 which then decreases between November 2007 and May 2008. But in general there is an increase in Ni contents between May 2007 and May 2008. It is interesting to note that this trend is independent of seasonal variability (flushing of polluted soils during high base flow conditions, evaporation or precipitation, etc).

4 Accumulative Signature of Heavy Metals

The earlier studies on the heavy metal contents has revealed that Co, Cd and Pb display short term accumulative trends at different sampling stations in the Chitgar river bed sediments near by the study area (Sayadi et al., 2010) and the concentrations of heavy metals in the top soils of Chitgar industrial area are remarkably higher than the natural local background (Sayadi et al., 2009). An increasing trend has been found for the heavy metal elements Cr, Cu, Ni and Zn along with Co, Cd and Pb in the river sediments and soil wherein the Pb and Cd are getting accumulated with very rapid rate attributed mainly due to an anthropogenic activities (Sayadi, 2009).

In order to assess the variations in the heavy metal accumulations in the soils the calculated measures i.e. Enrichment Factor and Normalized Scatter Coefficient were used. The Enrichment Factor (EF) is a ratio of the concentrations of the heavy metals in the soil samples (which are taken in May 2008) to the corresponding concentration of natural local background concentration. EF is calculated with the help of the formula given by Subramanian et al. (1998) and presented in Table 2.

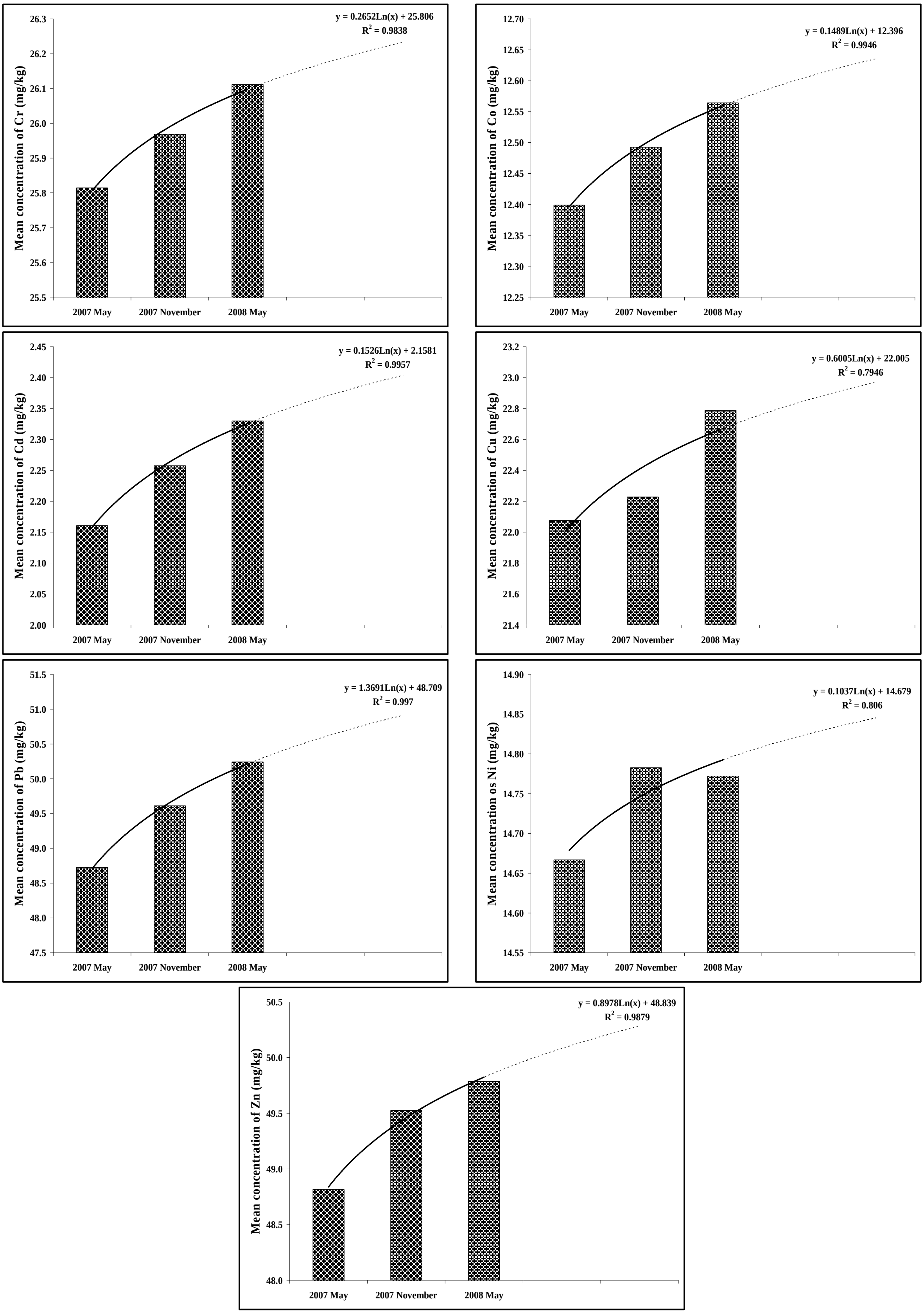

Fig. 2 Mean concentrations of the heavy metals in three different seasons with forecasted trends.

$$EF = \frac{\text{Value of a given metal concentration found on soil (mg/kg)}}{\text{Natural local background concebtration of the metal (mg/kg)}}.$$

Table 2 Enrichment Factor for heavy metals in the soils of study area.

Sampling stations	Cr	Co	Cd	Cu	Pb	Ni	Zn	Sampling stations	Cr	Co	Cd	Cu	Pb	Ni	Zn
1	2.2	1.9	6.4	3.1	5.6	1.3	4.9	36	2.1	1.7	8.1	2.2	10.1	1.4	5.4
2	2.7	1.5	5.4	3.1	7.8	1.3	3.9	37	2.9	1.4	6.6	2.3	11.7	1.2	5.4
3	2.6	1.5	6.9	3.1	7.5	1.2	3.9	38	2.5	1.3	7.2	2.5	11.5	1.5	5.6
4	1.8	1.3	4.8	2.9	5.5	1.1	3.4	39	2.9	1.6	8.7	2.6	11.5	1.2	5.6
5	2.9	1.7	6.4	3.1	9.3	1.5	4.7	40	2.9	1.6	6.5	2.8	13.2	1.1	5.6
6	2.1	1.6	6.0	2.6	8.0	1.7	4.1	41	1.4	1.6	5.6	2.0	11.5	1.1	4.3
7	2.3	1.4	5.1	1.4	7.9	1.2	4.1	42	2.3	1.6	3.9	1.9	9.2	1.1	3.9
8	3.5	1.8	6.7	2.5	8.1	1.3	5.2	43	2.3	1.6	5.0	1.5	10.3	1.2	4.3
9	3.2	1.5	6.1	1.5	7.6	1.2	4.3	44	3.4	1.6	6.3	2.9	11.6	1.7	4.4
10	1.6	1.7	5.6	1.6	7.2	1.2	2.9	45	3.2	1.5	7.6	1.5	8.3	1.5	4.3
11	1.7	1.5	4.7	2.6	7.8	1.2	3.7	46	1.9	1.5	7.4	1.7	7.7	1.3	3.6
12	1.3	1.7	8.4	2.8	7.5	1.3	4.1	47	1.9	1.6	7.0	2.8	8.7	1.2	4.1
13	2.9	1.6	8.1	2.5	8.6	1.4	4.6	48	3.5	1.6	8.7	3.5	9.9	1.3	4
14	3.4	1.7	6.9	2.5	7.1	1.3	3.8	49	2.6	1.6	10.1	3.0	9.2	1.3	4.7
15	2.7	1.0	6.7	3.0	12.0	1.3	4.9	50	3.6	2.1	8.7	2.7	11.5	1.3	4.9
16	2.5	1.7	5.9	3.2	12.2	1.7	5.4	51	3.3	1.8	6.6	2.6	10.2	1.3	4.9
17	3.5	1.6	5.5	2.8	12.7	1.2	3.8	52	4.3	1.8	8.5	2.4	9.9	1.2	5.9
18	3.5	1.4	5.2	2.8	13.1	1.1	3.4	53	3.3	1.9	8.6	2.6	11.2	1.3	4.6
19	3.4	1.5	5.0	3.0	11.7	1.2	2.8	54	2.5	1.4	7.3	3.0	11.4	1.4	4.4
20	2.8	1.6	7.6	2.6	10.1	1.6	4.5	55	2.8	1.4	5.0	2.9	11.7	1.2	4.3
21	2.0	1.7	6.6	2.0	8.2	1.4	4.8	56	1.9	1.3	5.1	1.8	8.7	1.1	3.8
22	2.1	1.3	6.1	2.1	8.7	1.4	4	57	2.2	1.4	5.8	1.2	10.0	1.1	2
23	1.7	1.2	3.8	1.2	8.5	1.4	4.6	58	1.7	1.5	5.5	1.6	9.9	1.2	3.4
24	1.3	1.4	3.6	1.8	6.5	1.5	4.7	59	1.9	1.3	6.0	1.8	10.5	1.5	3.8
25	1.5	1.3	7.0	1.4	7.3	1.3	2.7	60	3.0	1.7	7.2	2.9	11.6	1.7	5.2
26	2.4	1.2	5.4	3.0	9.4	1.2	2.6	61	1.1	1.7	8.7	1.5	11.2	1.4	4.4
27	1.6	1.4	5.7	1.7	5.9	1.1	3.9	62	2.3	2.0	7.7	1.8	12.7	1.2	4
28	1.5	1.5	5.4	1.9	7.9	1.2	3.8	63	2.9	1.6	5.8	1.8	12.3	1.2	3.9
29	2.9	1.4	8.7	2.8	12.3	1.2	5.7	64	2.7	1.6	5.9	1.2	9.4	1.2	4.2
30	2.9	1.7	7.9	2.7	12.3	1.5	6.4	65	1.5	1.6	6.9	3.3	9.0	1.3	2.3
31	2.3	1.4	9.2	2.6	11.6	1.5	5.1	66	1.8	1.7	5.7	2.1	8.6	1.1	4
32	1.4	1.5	9.8	3.0	8.6	1.6	4.7	67	3.7	1.7	5.4	1.9	10.1	1.2	4
33	3.7	1.5	9.0	1.4	10.3	1.4	3.3	68	3.6	1.7	9.6	1.9	9.5	1.2	4
34	3.6	2.0	9.2	3.7	11.2	1.5	5.8	69	3.3	1.8	8.2	2.0	10.1	1.2	4.8
35	1.9	1.7	8.9	2.3	10.1	1.5	4.3	70	2.7	1.8	12.7	3.0	9.9	1.2	4.7

Normalized scatter coefficient (NSC) has been calculated to assess the temporal variability of the heavy metals in the soils. It helps us to understand the increasing or decreasing concentration of heavy metals in the soils with the passage of time which is independent of the past focusing only at the period of study. The NSC for any element is calculated Table 3 with the following formula (Sayadi and Sayyed, 2010).

$$\text{NSC} = \frac{\text{Concentration in the last sampling - concentration in first sampling}}{\text{Concentration in the last sampling + concentration in first sampling}} \times 100,$$

The NSC values +100% indicates absolute increase while -100% means absolute decrease. The value of 0% can be regarded for no change in the parameters under consideration.

Table 3 Normalized scatter coefficient (%) of the heavy metals in the soils of the study area.

Sampling stations	Cr	Co	Cd	Cu	Pb	Ni	Zn	Sampling stations	Cr	Co	Cd	Cu	Pb	Ni	Zn
1	1	0	1	1	2	3	1	36	0	3	6	0	0	0	0
2	0	0	1	0	2	0	0	37	1	1	6	2	1	0	1
3	0	1	0	1	1	1	0	38	1	0	10	1	1	2	0
4	0	0	1	0	1	0	0	39	1	3	8	1	1	4	1
5	0	-2	3	1	2	2	1	40	0	0	4	0	1	0	1
6	1	0	-1	1	2	0	0	41	0	1	4	2	1	1	0
7	0	0	0	0	1	0	0	42	0	0	1	0	0	0	0
8	0	0	7	0	0	0	0	43	0	1	6	1	4	0	1
9	1	-2	0	1	0	0	0	44	0	0	3	2	2	1	0
10	0	1	-1	0	0	1	0	45	0	0	2	0	1	0	0
11	1	2	2	1	1	0	0	46	0	0	1	0	2	0	0
12	0	2	1	2	1	3	0	47	0	1	-3	1	1	4	3
13	1	0	9	8	0	0	0	48	2	2	3	1	1	2	1
14	0	1	3	0	1	0	1	49	1	2	8	1	1	0	23
15	0	0	2	0	1	0	0	50	3	2	8	1	11	2	0
16	0	0	2	1	1	1	0	51	2	0	4	3	3	0	1
17	1	0	1	1	0	0	0	52	1	2	9	2	1	2	1
18	0	0	2	0	0	1	0	53	2	3	17	3	2	2	1
19	0	1	2	0	1	2	1	54	3	1	8	-2	5	0	0
20	1	0	1	0	1	1	1	55	0	0	1	1	1	3	2
21	0	0	1	1	1	1	0	56	0	1	4	3	1	0	0
22	0	0	-1	1	1	1	0	57	0	0	3	7	2	2	0
23	-1	0	1	1	1	0	1	58	0	1	4	0	2	0	1
24	0	0	0	-2	1	0	0	59	0	1	5	7	1	1	1
25	0	0	0	0	1	0	0	60	1	2	-3	1	1	0	1
26	-6	0	1	1	2	1	2	61	0	1	4	1	1	1	1
27	0	0	1	7	3	0	2	62	0	2	6	1	1	2	1
28	0	-2	3	8	2	3	2	63	0	0	6	3	1	0	0
29	2	1	1	15	3	1	3	64	0	1	3	2	2	2	1
30	0	0	0	1	1	0	0	65	0	0	3	0	1	0	1
31	1	0	9	2	1	0	1	66	0	1	5	6	4	0	3
32	0	0	16	1	6	0	1	67	2	0	3	3	2	2	1
33	1	1	3	2	1	0	1	68	0	2	8	2	2	1	1
34	1	1	3	1	1	-22	0	69	1	1	3	2	1	2	1
35	0	0	1	2	3	1	1	70	2	3	9	2	1	1	1

5 Discussion

In order to evaluate the rate of accumulation of heavy metals in the soils the mean values for all heavy metals studied in three successive seasons were considered, along with the EF values of all seven elements (Table 2), which clearly indicate quite highest enrichment of Pb. The values of NSC for all seven heavy metals (Table 3) show that Cd is increasing in the soil environment with considerable pace followed by Cu, Pb and Zn while Ni, Co and Cr show rather slow increasing. Except for Cd and Zn in all other heavy metals, the enrichment factor is seen to be controlled by their mean concentrations in the soils (Fig. 3). Cd shows lowest concentration in soils but it has quite high enrichment factor, while Zn shows higher mean concentration but rather low enrichment factor when compared with Pb.

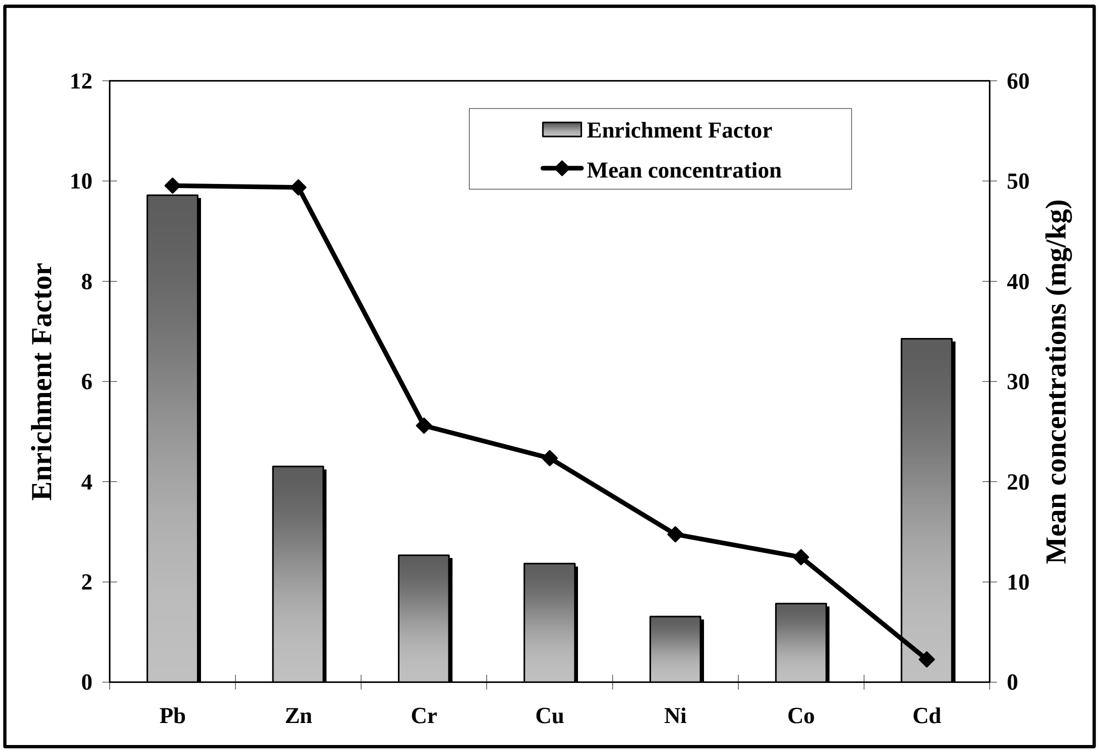

Fig. 3 Mean concentrations and Enrichment Factors for the heavy metals from the soils.

The scatter plot of the mean concentrations of the heavy metals was plotted against the enrichment factor (Fig. 4) which shows that Zn, even though is having higher mean concentration, is not getting enriched in proportion to its mean concentration. On the other hand Cd, though having lowest means concentration has higher rate of enrichment; Pb demonstrating highest mean value and corresponding highest enrichment. The behavior of Zn may be attributed to its source mainly from weathering of the parent rock while that of Cd and Pb mainly due to the anthropogenic activities. When the mean concentrations of the heavy metals were plotted against the NSC it is observed that Cd has highest NSC values, even with the small mean concentration (Fig. 5) again indicating quite high rate of accumulation. Enrichment factor normally reveals the addition and/or removal of metal under consideration which is a result of cumulative activity in the region. Hence the EF should denote the total enrichment and/or depletion of an element and can not evaluate the trend for the short term accumulation. The NSC can evaluate the enrichment and/or depletion of a particular element in the period of time with respect to the last sampling.

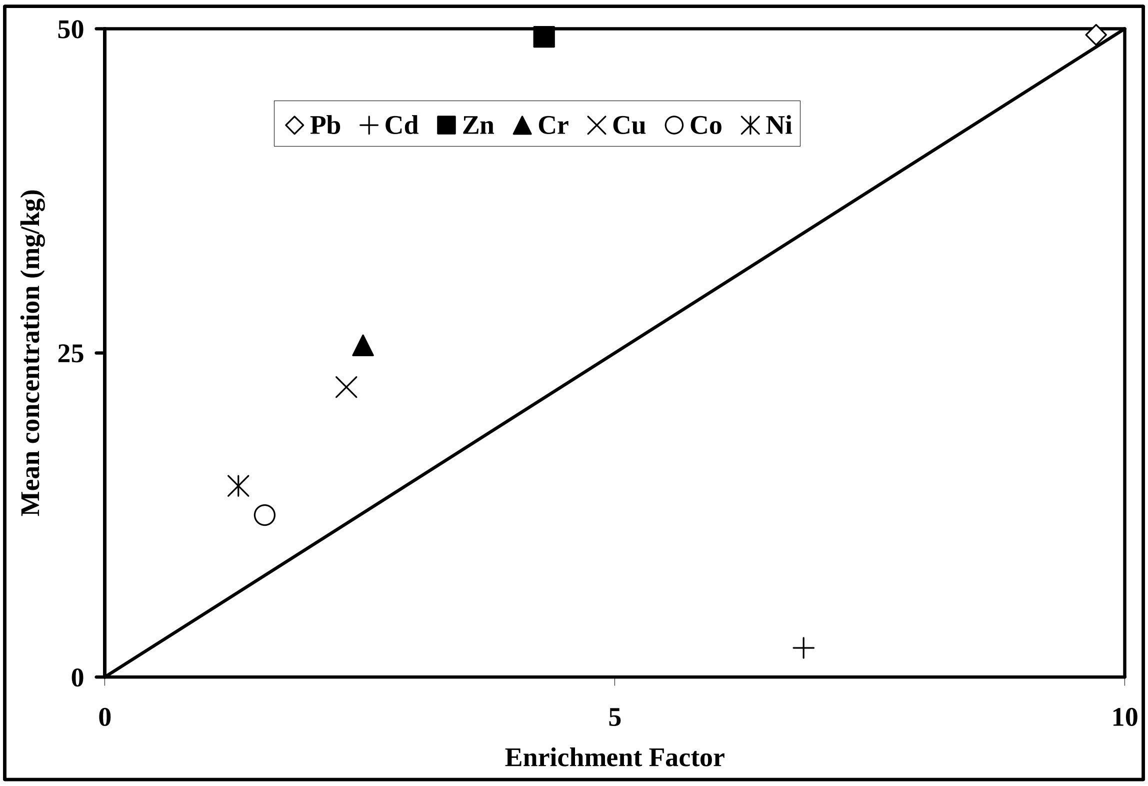

Fig. 4 Bivariate plot of the mean concentrations and enrichment factors of the heavy metals

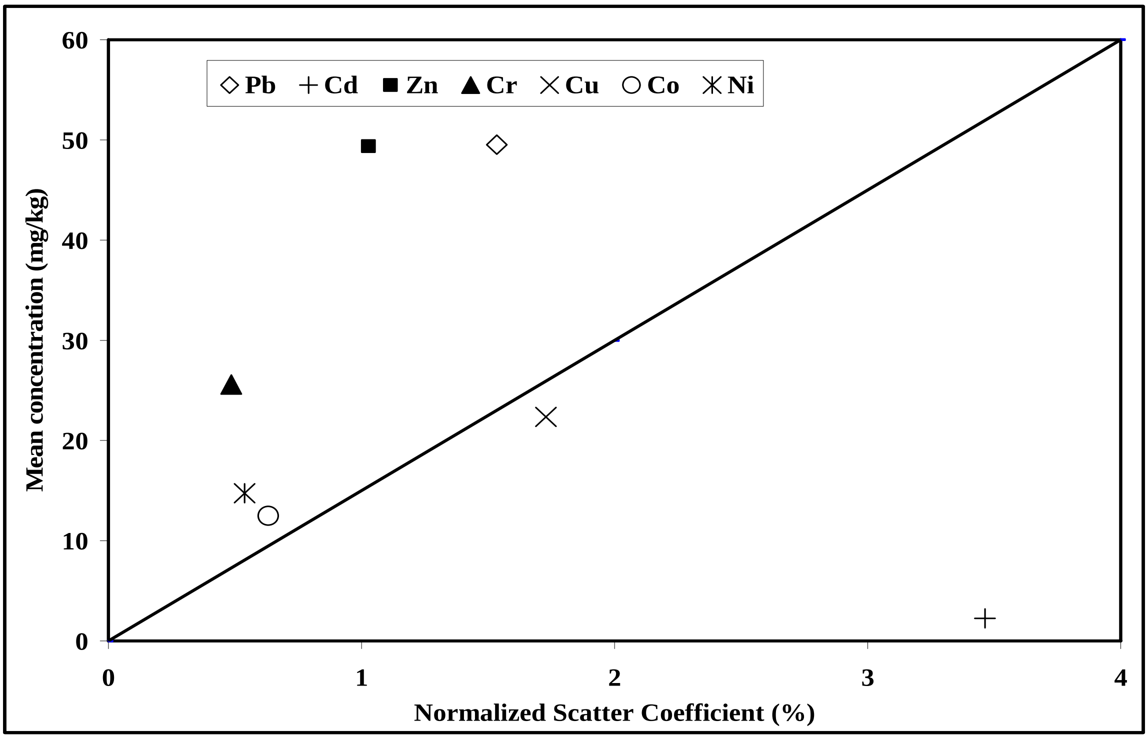

Fig. 5 Bivariate plot of the mean concentrations and normalized scatter coefficients of the heavy metals.

When the mean values of EF and NSC for all the seven heavy metals are studied together (Fig. 6) it can be stated that Pb has been enriched to quite great extent, followed by Cd, Zn, Cr, Cu, Co, and Ni when their EF values are considered. On the other hand the NSC values indicate that Cd is getting enriched with the faster rate, followed by Cu, Pb, Zn, Co, Ni and Cr.

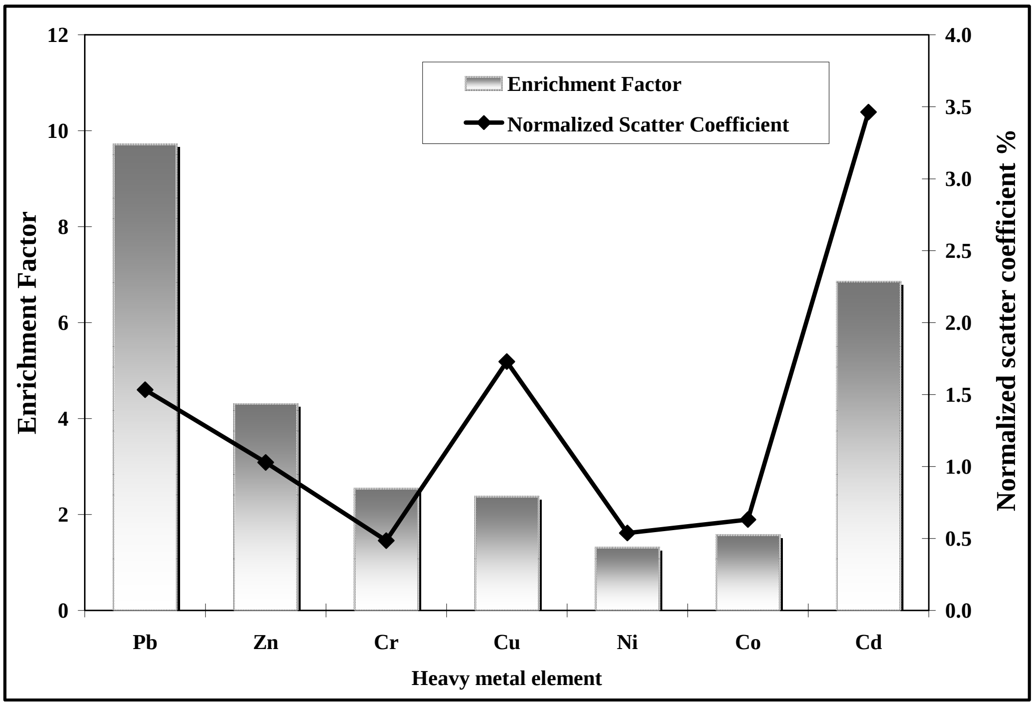

Fig. 6 Mean concentrations of Enrichment Factor and Normalized Scatter Coefficients for the heavy metals from the soils.

6 Conclusions

The variation assessment of heavy metal pollution by using the EF and NSC in the soil samples collected from the study area between May 2007 and May 2008 has reveled significant increase in the seven heavy metals (viz. Pb, Cd, Zn, Cr, Cu, Co, and Ni). EF values show that Pb has enriched to a great extent followed by Cd, Zn, Cr, Cu, Co and Ni, on the other hand, NSC values indicate that Cd is getting accumulated with faster rate, followed by Cu, Pb, Zn, Co, Ni and Cr. The rate of addition of Cd and Cu to the soils during the study period has been quite high as compared to their accumulative enrichment in the past.

In summary the soils in the Chitgar industrial area are significantly contaminated by heavy metals and hence more attention should be paid to heavy metal pollution, particularly for Pb and Cd. In order to prevent heavy metal contamination in the soils from the Chitgar industrial area and to maintain the ecological balance some immediate measures, as per environmental quality criteria, need to be taken.

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References

Burges TM, Webster R. 1980. Optimal interpolation and isarithmic mapping of soil properties. Journal of Soil Sciences, 31: 315-331

Burges TM, Webster R, Mc Bratney AB. 1981. Optimal sampling and isarithmic mapping of soil properties, IV-Sampling strategy. Journal of Soil Sciences, 32: 1028-1032

Committee of Soil Standard Methods for Analyses and Measurements. 1986. Soil Standard Methods for Analyses and Measurements. Hakuyusha, Tokyo, Japan

Fakoyade SO, Onianwa PC. 2002. Heavy metal contamination of soil and bioaccumulation in Guinea grass Panicumacium around Ikeja Industrial Estate, Lagos, Nigeria. Environmental Geology, 43: 145-150

Govil PK, Reddy GLN, Krishna AK. 2001. Contamination of soil due to heavy metals in Patancheru industrial development area, Andhra Pradesh, India. Environmental Geology, 41: 461-469

Haktanir KA, Erpul S, Tan G. 1995. Accumulation of traffic related heavy metals around highways. Tr. Journal of Engineering and Environmental sciences, 19: 423-431

Majdi HS, Persson H. 1989. Effect of road traffic pollutants lead and cadmium on tree fine-root along a motor road. Plant and Soil, 119: 1-5

Romic M, Romic D. 2003. Heavy metal distribution in agricultural top soils in urban area. Environmental Geology, 43: 795–805

Sayadi MH. 2009. Impact of heavy metal pollution of soils in Chitgar industrial area, Tehran. Dissertation, University of Pune

Sayadi MH, Sayyed MRG. 2010. Comparative assessment of baseline concentration of the heavy metals in the soils of Chitgar industrial area Tehran (Iran) with the comprisable reference data. Environmental Earth Sciences, DOI 10.1007/s12665-010-0792-z

Sayadi MH, Sayyed MRG, Shabani N. 2009. Quantification of heavy metal pollutants in the surface soils of Chitgar industrial area Tehran, Iran with spatial references to their spatial pattern. Pollution Research, 28: 345-351

Sayadi MH, Sayyed MRG, Suyash Kumar. 2010. Short-term accumulative signatures' of heavy metal in river bed sediments, Tehran Iran. Environmental Monitoring and Assessment, 162: 465-473

Subramanian V, Datta Dilip K. 1998. Distribution and fractionation of heavy metals in the surface sediment of the Gangae–Brahmaputra–Meghna river system in the Bengal basin. Environmental Geology, 36: 93-101