Pollution, 5(2): 387-394, Spring 2019
DOI: 10.22059/poll.2019.272090.555
Print ISSN: 2383-451X Online ISSN: 2383-4501
Web Page: https://jpoll.ut.ac.ir, Email: jpoll@ut.ac.ir

Evaluating the Potential of Plants (leaves) in Removal of Toxic Metals from Urban Soils (Case Study of a District in Tehran City)

Eghbal, N.,[1] Nasrabadi, T.,[2*] Karbassi, A.R.[3] and Taghavi, L.[1]

1. Faculty of Natural Resources & Environment, Science & Research branch, Islamic Azad University, Tehran, Iran

2. Department of Environmental Planning, Management and Education, School of Environment, College of Engineering, University of Tehran, Iran

3. Department of Environmental Engineering, School of Environment, College of Engineering, University of Tehran, Iran

Received: 22.05.2018 Accepted: 12.01.2019

ABSTRACT: Urban soil pollution has become a major concern in megacities around the world. Due to their non-degradable characteristic, toxic metals are among the most notorious pollutants. In this study determination of total and bioavailable fraction of toxic metals Ni, Cu, Cr, Zn, Co, Cd, Pb and Mn, in surface soils of district 16th in Tehran municipality is considered. Furthermore, metals uptake potential of a variety of endemic plants is also investigated. Forty one surface soil samples and eleven composite leaf samples were collected within the study area in winter 2015. Except for Cd and Pb, other toxic metals showed generally lower concentrations in comparison with shale and mean earth crust values. Intensified traffic load within the district may be considered as the main reason for such augmented concentrations. The order of bioavailable fraction from total metal concentrations detected to be as: Zn(2.78%) > Cd(2.71%) > Co(1.92%) > Mn(1.79%) > Cu(1.59%) > Pb(.89%) > Ni(.7%) > Cr(.4%). Concentration of different metals in leaf samples revealed that berry, eucalyptus, plane and acacia are more capable in comparison with others in translocating toxic metals from soil. Paying more attention to pollution removal capability of urban plants may play a key role in sustainable municipal management of megacities like Tehran.

Keywords: Urban soil, Toxic metals, Bioavailable fraction, Translocation factor, Plant leaf.

INTRODUCTION

Soil as a reciprocal media (both source and sink of metallic pollution) has been widely studied so far and a variety of detection, monitoring and reclamation techniques are introduced by different researchers (Mehrdadi et al., 2009; Nasrabadi et al., 2010; Afkhami et al., 2013; Karbassi et al., 2014; Nasrabadi et al., 2016). Plants are used by many researchers to show the intensity of pollution in urban areas as well as road sides that are originated from various sources (Tomašević et al., 2004). Many researchers have successfully used various types of plant as a means of phytoremediation to clean up the metal contents of soils as well as water bodies. Some researchers have used the tree

* Corresponding Author Email: tnasrabadi@ut.ac.ir

leaves as the bio-indicators of pollution in the urban areas (Singh et al., 2005; Tomaševič et al., 2008; Estrabou et al., 2011; Chandrasekhar and Ray, 2019; Jiang et al., 2019). Tree leaves located in the vicinity of roads and urban areas can contain elevated Pb and other trace metals (Bi et al., 2013; Ogbonnar et al., 2013; Yu et al., 2012). It should be noted that such studies may take into consideration the trace metal contents available on the surface of the leaves or they may consider the metal contents that are up-taken by the plants. Many researcher opine that bioavailability of metals provide more useful information on the trace metal contents that can show both the health of the plants as well as the degree of pollution in the surrounding environment (Singh and Kalamdhad, 2011; Wei and Yang, 2010). The up-take of metals by plants depends on many factors including the texture of soil, pH, organic contents and many other parameters (Feng et al., 2005; Smolders et al., 2009; Peijnenburg and Jager, 2003). However, the natural conditions of soils in urban area undergo many changes as a result of human activities. For instance deicing of streets by various salts during winter time may alter the physical and chemical properties of soil (Findlay and Kelly, 2011; Davison, 1971). The main goals of this study are i) to determine the total and bioavailable concentration of toxic metals in surface soils of an urban area in Tehran city and ii) to evaluate the potential of a variety of endemic plants leaves for up-taking the soil metallic pollution.

With an approximate surface area of 1651 hectares, district 16th is located in southern parts of Tehran city. More than three hundred thousand people live in this district. An intensive road network of more than seventy kilometers, several subway and bus stations, the main bus terminal in Southern Tehran and the main train station of the city are considered as the main features of this area. Accordingly, heavy quotidian traffic loads are observed within the boundaries of this district. In order to have a thorough knowledge over the whole district a virtual mesh grid was considered over the whole surface area and composite soil and plants leaves samples were collected from each grid in winter 2015. The location of 41 sampling stations within the district 16th of Tehran city, as well as the location of the city within the country is demonstrated in Fig.1.

MATERIALS AND METHODS

Surface soil and leaf samples were collected in plastic bags and sent to the laboratory for analysis. Leaf samples were completely washed by water to assure the removal of any probable metallic pollution caused by polluted air deposition.

Soil samples were dried at room temperature and were filtered to reach the grain size less than 63 microns. Details for digestion of soil samples to detect the total concentration are described in Fazeli et al., (2018). 0.5 gram of the powder was digested by a mixture of HNO_3 and HCl (3:1 volumetric ratio), heated and added to 3 ml of $HClO_4$. The substrate was cooled down, filtered and reached to the volume of 50 ml with 1N HCl. To quantify the bioavailable concentration of metals 10g of sieved samples were digested by a mixture of NaOH (1 N) and acetic acid for 30 minutes at pH 5 and refluxed for twenty four hours (Hosseini Alhashemi et al., 2011).

The leaves of plant samples were powdered and about 1g of each sample was treated by a mixture of HNO_3 and $HClO_4$ (4:1) in high density polyethylene bakers. The temperature was kept at 125 ^{o}C throughout the digestion procedure (Li et al., 2004; Luo et al., 2011).

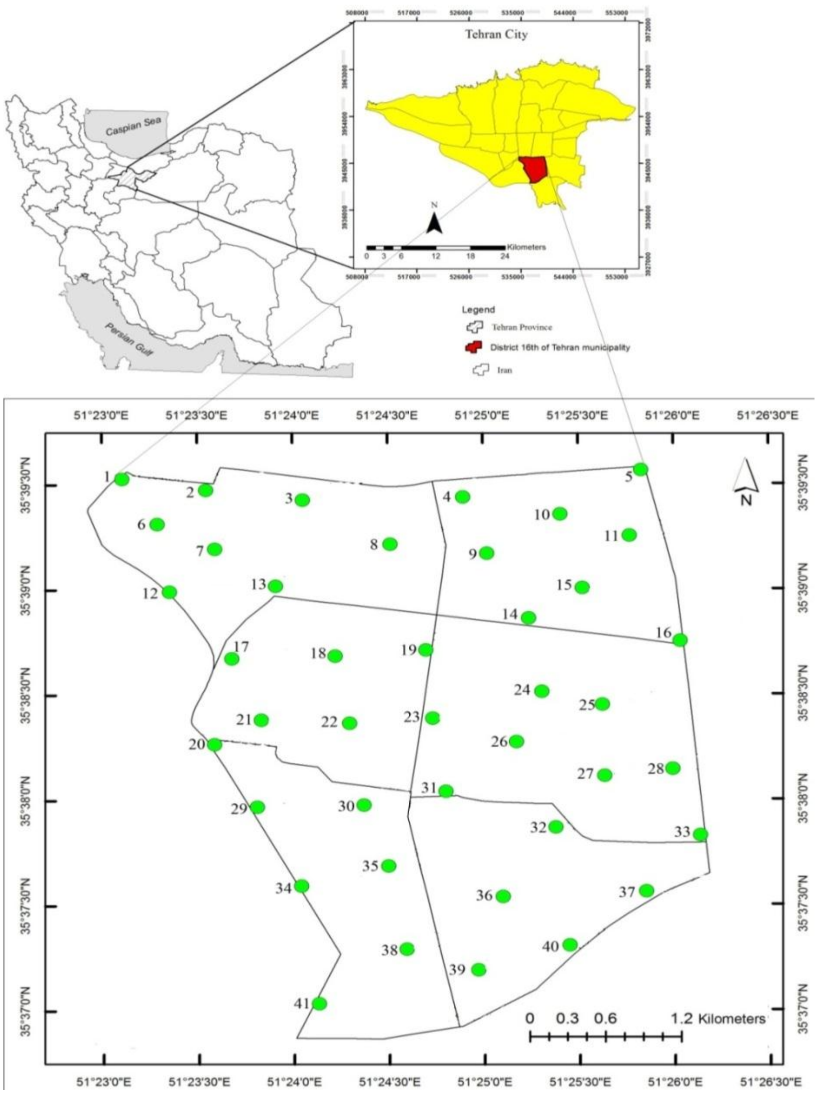

Fig. 1. Location of Tehran city, district 16th and sampling stations within the study area

Concentration of metals in both filtrates (soils and leaves) was detected by an inductively coupled plasma optical emission spectrometer (ICPOES). Some samples were analyzed in duplicates and triplicates and assured the required precision (coefficient of variation less than 10%).

RESULTS & DISCUSSIONS

Surface soil samples were analyzed for total concentration of toxic metals nickel, copper, cadmium, chromium, zinc, cobalt, lead and manganese. Detected concentrations were compared with shale (Alloway, 1995) and mean earth crust values (Turekian and Wedepohl, 1961) as guidelines. Furthermore, bioavailable concentration of mentioned metals (both in mg/kg and percentage of total concentration) are demonstrated (Table 1).

Co, Ni and Mn showed concentrations lower than shale and mean earth crust in all 41 surface soil samples. In case of Zn, Cu and Cr, concentrations are generally in line with reference values except for a few samples that

Table 1. Total (Tot) and bioavailable (Bio) concentration of toxic metals (in mg/kg dry weight) and bioavailable percentage of total concentration in surface soil samples

Station	Ni			Cu			Cr			Zn			Co			Cd			Pb			Mn		
	Tot	Bio	Bio%	Tot	Bio	Bio%	Tot	Bio	Bio%	Tot	Bio	Bio%	Tot	Bio	Bio%	Tot	Bio	Bio%	Tot	Bio	Bio%	Tot	Bio	Bio%
1	31	0.4	1.29	41	0.8	1.95	42	0.1	0.24	91	3.2	3.52	18	0.8	4.44	3.7	0.11	3.09	39	0.1	0.26	607	10	1.65
2	22	0.1	0.45	25	0.5	2.00	31	0.2	0.65	56	1.9	3.39	11	0.3	2.73	2.3	0.09	3.73	31	0.2	0.65	249	7	2.81
3	41	0.5	1.22	38	0.6	1.58	53	0.1	0.19	39	1.5	3.85	15	0.1	0.67	1.9	0.06	3.01	43	0.3	0.70	351	5	1.42
4	23	0.1	0.43	22	0.5	2.27	32	0.1	0.31	60	2.1	3.50	10	0.2	2.00	2.6	0.09	3.30	30	0.3	1.00	228	4	1.75
5	39	0.1	0.26	53	0.5	0.94	51	0.2	0.39	51	1.6	3.14	15	0.3	2.00	3.1	0.09	2.76	55	0.5	0.91	353	7	1.98
6	35	0.2	0.57	35	0.4	1.14	45	0.1	0.22	31	1	3.23	16	0.2	1.25	2.8	0.09	3.06	31	0.4	1.29	309	5	1.62
7	36	0.1	0.28	51	0.7	1.37	50	0.1	0.20	52	1.7	3.27	15	0.3	2.00	3.3	0.11	3.46	53	0.4	0.75	601	9	1.50
8	42	0.3	0.71	33	0.5	1.52	56	0.2	0.36	94	3	3.19	17	0.1	0.59	2.4	0.09	3.57	34	0.3	0.88	511	12	2.35
9	38	0.1	0.26	31	0.5	1.61	47	0.1	0.21	90	3.1	3.44	14	0.2	1.43	1.7	0.03	1.68	28	0.1	0.36	355	7	1.97
10	40	0.3	0.75	30	0.5	1.67	55	0.3	0.55	100	3	3.00	15	0.3	2.00	3.1	0.06	1.84	30	0.4	1.33	451	7	1.55
11	41	0.1	0.24	46	0.6	1.30	52	0.1	0.19	29	0.9	3.10	15	0.2	1.33	3.3	0.11	3.46	60	0.7	1.17	413	6	1.45
12	28	0.3	1.07	25	0.4	1.60	33	0.1	0.30	49	1.6	3.27	11	0.3	2.73	3	0.09	2.86	26	0.3	1.15	215	4	1.86
13	37	0.1	0.27	32	0.5	1.56	59	0.2	0.34	25	0.7	2.80	15	0.1	0.67	3.2	0.09	2.68	28	0.1	0.36	356	7	1.97
14	35	0.3	0.86	25	0.5	2.00	47	0.1	0.21	68	2.1	3.09	13	0.2	1.54	2.7	0.06	2.12	33	0.4	1.21	258	4	1.55
15	33	0.6	1.82	53	0.7	1.32	43	0.3	0.70	95	2.4	2.53	15	0.3	2.00	2	0.03	1.43	56	0.5	0.89	451	8	1.77
16	35	0.2	0.57	43	0.5	1.16	45	0.4	0.89	28	0.6	2.14	14	0.2	1.43	2.3	0.06	2.48	30	0.3	1.00	458	8	1.75
17	31	0.3	0.97	35	0.4	1.14	51	0.1	0.20	31	0.6	1.94	13	0.3	2.31	3.1	0.11	3.69	35	0.3	0.86	513	9	1.75
18	48	0.1	0.21	93	1.7	1.83	72	0.5	0.69	45	1.3	2.89	15	0.1	0.67	3.3	0.14	4.33	69	0.6	0.87	610	11	1.80
19	29	0.2	0.69	36	0.4	1.11	36	0.1	0.28	81	2.1	2.59	12	0.2	1.67	3.2	0.09	2.68	28	0.1	0.36	367	8	2.18
20	40	0.3	0.75	30	0.4	1.33	43	0.1	0.23	85	2	2.35	16	0.3	1.88	1.9	0.03	1.50	29	0.3	1.03	581	13	2.24
21	44	0.2	0.45	32	0.5	1.56	54	0.2	0.37	33	1.4	4.24	16	0.2	1.25	2.2	0.06	2.60	30	0.3	1.00	388	6	1.55
22	31	0.3	0.97	35	0.5	1.43	41	0.1	0.24	26	0.7	2.69	15	0.3	2.00	3.3	0.11	3.46	40	0.4	1.00	251	4	1.59
23	30	0.1	0.33	27	0.4	1.48	47	0.3	0.64	80	2.1	2.63	12	0.1	0.83	3.1	0.09	2.76	34	0.4	1.18	417	5	1.20
24	32	0.2	0.63	81	1.3	1.60	52	0.1	0.19	138	3.7	2.68	13	0.2	1.54	2.9	0.09	2.96	73	0.8	1.10	402	6	1.49

Table 1. (Continued)

Station	Ni			Cu			Cr			Zn			Co			Cd			Pb			Mn		
	Tot	Bio	Bio %	Tot	Bio	Bio %	Tot	Bio	Bio %	Tot	Bio	Bio %	Tot	Bio	Bio %	Tot	Bio	Bio %	Tot	Bio	Bio %	Tot	Bio	Bio %
25	30	0.3	1.00	92	1.4	1.52	42	0.3	0.71	154	4.1	2.66	16	0.3	1.88	2.6	0.06	2.20	79	0.9	1.14	371	6	1.62
26	37	0.2	0.54	26	0.4	1.54	36	0.1	0.28	85	2.7	3.18	12	0.2	1.67	1.9	0.03	1.50	31	0.3	0.97	272	3	1.10
27	29	0.4	1.38	20	0.4	2.00	35	0.3	0.86	66	1.4	2.12	17	0.4	2.35	2.4	0.06	2.38	32	0.2	0.63	213	5	2.35
28	25	0.2	0.80	91	1.6	1.76	33	0.1	0.30	91	2.9	3.19	11	0.2	1.82	1.7	0.03	1.68	53	0.5	0.94	240	4	1.67
29	44	0.7	1.59	55	0.8	1.45	61	0.3	0.49	35	0.9	2.57	18	0.7	3.89	2.2	0.09	3.90	49	0.5	1.02	531	8	1.51
30	41	0.4	0.98	33	0.6	1.82	63	0.4	0.63	27	0.5	1.85	15	0.2	1.33	3.4	0.09	2.52	33	0.3	0.91	379	7	1.85
31	38	0.1	0.26	51	0.9	1.76	54	0.1	0.19	98	3.1	3.16	15	0.3	2.00	2.5	0.09	3.43	30	0.3	1.00	363	8	2.20
32	25	0.5	2.00	34	0.6	1.76	37	0.5	1.35	33	0.6	1.82	15	0.2	1.33	3.5	0.09	2.45	31	0.2	0.65	509	8	1.57
33	27	0.1	0.37	45	0.7	1.56	45	0.1	0.22	30	0.5	1.67	14	0.4	2.86	3	0.06	1.90	35	0.4	1.14	366	9	2.46
34	45	0.1	0.22	53	1	1.89	56	0.1	0.18	50	0.9	1.80	15	0.2	1.33	2.8	0.09	3.06	40	0.3	0.75	519	6	1.16
35	38	0.2	0.53	35	0.6	1.71	41	0.2	0.49	29	0.7	2.41	18	0.7	3.89	2.5	0.06	2.29	30	0.3	1.00	218	5	2.29
36	42	0.1	0.24	61	1.1	1.80	40	0.1	0.25	32	0.6	1.88	17	0.5	2.94	1.8	0.03	1.59	70	0.8	1.14	367	6	1.63
37	45	0.3	0.67	42	0.7	1.67	56	0.3	0.54	30	0.5	1.67	14	0.4	2.86	2.6	0.03	1.10	55	0.4	0.73	266	3	1.13
38	41	0.1	0.24	30	0.5	1.67	42	0.1	0.24	88	2.5	2.84	15	0.3	2.00	3.6	0.14	3.97	35	0.3	0.86	220	6	2.73
39	46	0.3	0.65	26	0.4	1.54	73	0.3	0.41	75	2	2.67	16	0.4	2.50	3.3	0.11	3.46	33	0.2	0.61	249	3	1.20
40	40	0.1	0.25	29	0.4	1.38	45	0.1	0.22	31	1.1	3.55	15	0.2	1.33	3.5	0.10	2.86	45	0.3	0.67	270	5	1.85
41	33	0.3	0.91	55	1	1.82	50	0.2	0.40	149	4	2.68	15	0.3	2.00	2.7	0.06	2.12	61	0.6	0.98	510	11	2.16
Min	22	0.1	0.21	20	0.4	0.94	31	0.1	0.18	25	0.5	1.67	10	0.1	0.59	1.7	0.03	1.10	26	0.1	0.26	213	3	1.10
Max	48	0.7	2	93	1.7	2.27	73	0.5	1.35	154	4.1	4.24	18	0.8	4.44	3.7	0.14	4.33	79	0.9	1.33	610	13	2.81
Mean	35.78	0.24	0.70	42.20	0.67	1.59	47.46	0.19	0.40	62.93	1.79	2.78	14.61	0.29	1.92	2.74	0.08	2.71	41.15	0.37	0.89	379.46	6.71	1.79
SD	6.72	0.15	0.45	18.81	0.33	0.28	10.04	0.12	0.25	34.85	1.05	0.62	1.96	0.16	0.87	0.57	0.03	0.80	14.43	0.19	0.26	120.86	2.45	0.42
MEC*	80	–	–	50	–	–	100	–	–	75	–	–	20	–	–	0.1	–	–	14	–	–	950	–	–
Shale**	68	–	–	39	–	–	39	–	–	120	–	–	19	–	–	0.22	–	–	23	–	–	850	–	–

* Mean Earth Crust (Alloway, 1995)
**(Turekian and Wedepohl, 1961)

negligible exceedance is observed. On the contrary, Cd and Pb showed remarkably higher concentrations in comparison with shale and mean earth crust. According to Table 1 descending order of bioavailable contribution from bulk metal concentrations detected to be as: Zn (2.78%) > Cd (2.71%) > Co (1.92%) > Mn (1.79%) > Cu (1.59%) > Pb (.89%) > Ni (.7%) > Cr (.4%).

Furthermore, a variety of plants (leaves samples) from different green spaces/parks of the district namely grass, plane, berry, cypress, black pine, Tehran pine, asparagus, elm, acacia, eucalyptus and silver cider were analyzed for mentioned metals. As it is seen in Table 2 highest concentrations in mg/kg of Cd (.09), Ni (10.8) and Cr (9.1) are detected in berry leaves. Additionally, eucalyptus leaves contains maximum values of Zn (321), Co (2.7), Pb (7.3) and Cu (44) in comparison with other plants.

Translocation factors (TFs) were calculated to evaluate the metal uptake potential of different plants (Table 3). Results showed that berry, plane, acacia and eucalyptus trees have relatively higher translocation factors (soil to leaves) in comparison with others. Translocation factor (TF) values of plane, berry and eucalyptus were calculated to be .14, .11 and .18 for lead, .15, .19 and .15 for chromium, .16, .3 and .25 for nickel and .02, .03 and .007 for cadmium, respectively.

Table 2. Mean concentration of metals in leaf samples (mg/kg dry weight)

Plant	Cd	Zn	Co	Ni	Pb	Mn	Cu	Cr
Grass	.01	67	1.7	2.9	2.3	183	5.1	ND*
Plane	.06	101	2.2	5.9	5.8	29.3	10.4	7.2
Berry	.09	293	1.6	10.8	4.6	142	35	9.1
Silver Cider	.02	51	1.5	5.2	2.7	62	7.2	5.1
Cypress	ND	42	1.7	5.6	2.1	59	6.1	4.8
Black Pine	.03	31	1.9	4.5	1.8	67	5.2	3.5
Tehran Pine	ND	39	1.8	3.9	1.5	51	4.9	2.4
Asparagus	ND	47	2.5	4.4	1.3	73	6.7	1.7
Elm	.01	40	1.3	5.3	1.6	55	7.4	2.2
Acacia	.03	49	2.3	6.1	4.9	209	31	6.1
Eucalyptus	.02	321	2.7	9.1	7.3	104	44	6.9

*not detected

Table 3. Translocation factor of different plants (soil to leaf organ) for toxic metals

Plant	Cr	Cu	Mn	Pb	Ni	Co	Zn	Cd
Grass	0.004	1.06	0.08	0.06	0.48	0.17	0.12	ND
Plane	0.022	1.60	0.16	0.14	0.08	0.12	0.25	0.15
Berry	0.033	4.66	0.30	0.11	0.37	0.22	0.83	0.19
Silver Cider	0.007	0.81	0.15	0.07	0.16	0.15	0.17	0.11
Cypress	ND	0.67	0.16	0.05	0.16	0.14	0.14	0.10
Black Pine	0.011	0.49	0.13	0.04	0.18	0.16	0.12	0.07
Tehran Pine	ND	0.62	0.11	0.04	0.13	0.14	0.12	0.05
Asparagus	ND	0.75	0.12	0.03	0.19	0.17	0.16	0.04
Elm	0.004	0.64	0.15	0.04	0.14	0.11	0.18	0.05
Acacia	0.011	0.78	0.17	0.12	0.55	0.07	0.73	0.13
Eucalyptus	0.007	5.10	0.25	0.18	0.27	0.18	1.04	0.15

CONCLUSIONS

Total and bioavailable concentration of toxic metals nickel, copper, cadmium, chromium, zinc, cobalt, lead and manganese in forty one surface soil samples of a district in Tehran city are measured in this study. Except for Cadmium and lead that their mean concentrations showed around 27(13) and 3(2) times higher than mean earth crust (shale) values respectively, other toxic metals showed generally lower values in comparison with guidelines. Remarkably high concentrations of Cd and Pb may be attributed to heavy traffic load within the boundaries of this district where the main train station and bus terminal of the city is located. Regarding bioavailable fraction of metals, Zn and Cd with 2.78 and 2.71 percent of total concentration showed the highest values while Pb, Ni and Cr indicated values less than unit. Despite low values of metals bioavailable fraction, the non-degradable nature of these pollutants and subsequently their bioaccumulation may be considered as a quotidian perilous risk. Furthermore, concentration of mentioned metals were analyzed in leaf samples of eleven endemic plants namely grass, plane, berry, cypress, black pine, Tehran pine, asparagus, elm, acacia, eucalyptus and silver cider. TFs of different plants were also calculated and berry, plane, acacia and eucalyptus trees were revealed to have relatively higher TF (soil to leaves) values. Making use of plants showing higher potentials in toxic metals uptake from urban soils may be further investigated from different points of view.

REFERENCES

Afkhami, F., Karbassi, A. R., Nasrabadi, T. and Vosoogh, A. (2013). Impact of oil excavation activities on soil metallic pollution, case study of an Iran southern oil field. Environmental earth sciences, 70(3), 1219-1224.

Alloway, B.J. (1995). Heavy metals in soils, Blackie Academic & Professional, London (2nd ed.)

Bi, X., Liang, S. and Li, X. (2013). Trace metals in soil, dust, and tree leaves of the urban environment, Guangzhou, China. Chinese Science Bulletin, 58(2), 222-230.

Chandrasekhar, C. and Ray, J. G. (2019). Lead accumulation, growth responses and biochemical changes of three plant species exposed to soil amended with different concentrations of lead nitrate. Ecotoxicology and Environmental Safety, 171, 26-36.

Davison, A. W. (1971). The effects of de-icing salt on roadside verges. I. Soil and plant analysis. Journal of Applied Ecology, 555-561.

Estrabou, C., Filippini, E., Soria, J. P., Schelotto, G. and Rodriguez, J. M. (2011). Air quality monitoring system using lichens as bioindicators in Central Argentina. Environmental monitoring and assessment, 182(1-4), 375-383.

Fazeli, G., Karbassi, A. R., Khoramnejadian, Sh. and Nasrabadi, T. (2018). Anthropogenic share of metal contents in soils of urban areas. Pollution, 4(4), 697-706.

Findlay, S. E. and Kelly, V. R. (2011). Emerging indirect and long-term road salt effects on ecosystems. Annals of the New York Academy of Sciences, 1223(1), 58-68.

Feng, M. H., Shan, X. Q., Zhang, S. and Wen, B. (2005). A comparison of the rhizosphere-based method with DTPA, EDTA, $CaCl_2$, and $NaNO_3$ extraction methods for prediction of bioavailability of metals in soil to barley. Environmental Pollution, 137(2), 231-240.

Hosseini Alhashemi, A.S., Karbassi, A.R., Hassanzadeh Kiabi, B., Monavari, S.M. and Nabavi, S.M.B. (2011). Accumulation and bioaccessibility of trace elements in wetland sediments. Afr J Biotechnol 10(9):1625–1636.

Jiang, M., Liu, S., Li, Y., Li, X., Luo, Z., Song, H. and Chen, Q. (2019). EDTA-facilitated toxic tolerance, absorption and translocation and phytoremediation of lead by dwarf bamboos. Ecotoxicology and Environmental Safety, 170, 502-512.

Karbassi, A., Nasrabadi, T., Rezai, M. and Modabberi, S. (2014). Pollution with metals (As, Sb, Hg, Zn) in agricultural soil located close to Zarshuran gold mine, Iran. Environmental Engineering and Management Journal, 13(1), 115-122.

Li, X., Lee, S. L., Wong, S. C., Shi, W. and Thornton, I. (2004). The study of metal contamination in urban soils of Hong Kong using a GIS-based approach. Environmental Pollution, 129(1), 113-124.

Luo, C., Liu, C., Wang, Y., Liu, X., Li, F. Zhang, G., and Li, X. (2011). Heavy metal contamination in soils and vegetables near an e-waste processing site, south China. Journal of hazardous materials, 186(1), 481-490.

Mehrdadi, N., Nabi Bidhendi, G. R., Nasrabadi, T., Hoveidi, H., Amjadi, M. and Shojaee, M. A. (2009). Monitoring the arsenic concentration in groundwater resources, case study: Ghezel ozan water basin, Kurdistan, Iran. Asian journal of chemistry, 21(1), 446-450.

Nasrabadi, T., Ruegner, H., Sirdari, Z. Z., Schwientek, M. and Grathwohl, P. (2016). Using total suspended solids (TSS) and turbidity as proxies for evaluation of metal transport in river water. Applied Geochemistry, 68, 1-9.

Nasrabadi, T., Nabi Bidhendi, G.R., Karbassi, A.R. Mehrdadi, N. (2010). Evaluating the efficiency of sediment metal pollution indices in interpreting the pollution of Haraz River sediments, southern Caspian Sea basin. Environ Monit Assess 171(1-4):395-410.

Ogbonna, C. E., Enete, C. I., Egedeuzu, C. S. and Ogbochi, F. (2013). Heavy metal concentration in leaves of roadside trees in Umuahia Urban, South East Nigeria. Resources and Environment, 3(5), 141-144.

Peijnenburg, W. J. G. M. and Jager, T. (2003). Monitoring approaches to assess bioaccessibility and bioavailability of metals: matrix issues. Ecotoxicology and environmental safety, 56(1), 63-77.

Singh, J. and Kalamdhad, A. S. (2011). Effects of heavy metals on soil, plants, human health and aquatic life. International journal of Research in Chemistry and Environment, 1(2), 15-21.

Singh, M., Goel, P. and Singh, A. K. (2005). Biomonitoring of lead in atmospheric environment of an urban center of the Ganga Plain, India. Environmental monitoring and assessment, 107(1-3), 101-114.

Smolders, E., Oorts, K., Van Sprang, P., Schoeters, I., Janssen, C. R., McGrath, S. P. and McLaughlin, M. J. (2009). Toxicity of trace metals in soil as affected by soil type and aging after contamination: using calibrated bioavailability models to set ecological soil standards. Environmental Toxicology and Chemistry, 28(8), 1633-1642.

Tomašević, M., Rajšić, S., Đorđević, D., Tasić, M., Krstić, J. and Novaković, V. (2004). Heavy metals accumulation in tree leaves from urban areas. Environmental Chemistry Letters, 2(3), 151-154.

Tomaševič, M., Vukmirovič, Z., Rajšič, S., Tasič, M. and Stevanovič, B. (2008). Contribution to biomonitoring of some trace metals by deciduous tree leaves in urban areas. Environmental monitoring and assessment, 137(1-3), 393.

Turekian, K.K. and Wedepohl, K.H. (1961). Distribution of the elements in some major units of Earth's crust. Bull Geol Soc Am 72:175–192.

Wei, B. and Yang, L. (2010). A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. Microchemical journal, 94(2), 99-107.

Yu, S., Zhu, Y. G. and Li, X. D. (2012). Trace metal contamination in urban soils of China. Science of the total environment, 421, 17-30.