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The Impact of Anjir –tangeh Coal Washing Plant on Concentration of Some Heavy Metals in the Native Vegetation, Mazandaran Province, Iran

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Abstract

A large volume of tailings has been produced in Anjir-tangeh coal washing plant for 22 years of human activity. The coal washing activities have reduced plant diversity near the plant. The environmental impact of coal washing plant on the vegetation around the factory was studied in two seasons. The concentrations of Pb, Cd and Cr, measured in different native plant species, were in normal ranges in summer. In fall, the concentrations of Pb, Cd and Cr in the plants around the factory were similar to those in plants in the control area. In summer, however, the metal concentrations were considerably higher in plants grown near the factory than in the plants of the control area. This difference was statistically significant at 0.01 levels for Cd, but not for Pb and Cr. Among the studied plant species, *Oxalis* Sp had the highest Cd concentration (0.409 ppm), but *Chenopodium album L* had the lowest Cr concentration in summer. Season was an effective factor in the uptake of heavy metals by plants; metal concentration in plants was considerably higher in fall than in summer.

Keywords: *coal washing plant, environmental impact, plants, Anjir-tange, heavy metal pollution.*

1. Introduction

Coal used to be known as burning rock and believed to possess supernatural power [1]. Coal processing, which is done in coal washing plant, produces a large volume of waste. During weathering the coal waste, especially coal tailings, acid mine drainage is produced. Acidic mine drainage (AMD) is formed when pyrite reacts with air and water to form sulfuric acid and dissolved iron. This acid run-off dissolves heavy metals that may end up in ground and surface waters, causing a significant reduction in the quality of the water and marking impact on the aquatic life and plants [2-5]. Increase in heavy metals in soil and water is considered as a danger to animals and the environment. The increase in concentrations of heavy metals in the soil causes stress in plants and results in reduced plant growth and can eventually lead to plant death [6]. Toxic effects in plants may also vary in certain seasons and appearance forms [7]. Further, symptoms of plant toxicity caused by heavy metals depend on the conditions, plant species and metal. Common symptoms include chlorosis, brown spots on leaves, low growth or gigantism and root deformities [8]. These plants prevent metals from entering their bodies or tolerate high concentration of metals in their tissues [9].

The elevated Cu, Cd, Pb and Mn of the tailings in mine land seem likely to impose toxic effects on plant establishment in addition to other constraints like nutrient deficiency and poor physical structure [10]. Evaluation of coal mine spoil dump on Ljkura coal mine in India and KD Heslong Coalfields in China showed that it is extremely difficult to revegetate, due to physical or chemical limitations to plant growth [11, 12].

Roy *et al*. (2010) reported heavy metal accumulation and changes in metabolic parameters in *Cajanas cajan* grown in coal mine spoil of Coal field in Dhanbad of Jharkhand state located in Eastern part of India [13].

Study of phytoremediation of mercury and arsenic from tropical opencast coalmine effluent through naturally occurring aquatic macrophytes shows that three aquatic macrophytes i.e. *Eichhornia crassipes, Lemna minor,* and *Spirodela polyrrhiza* can be used for uptake of Hg and As from AMD [14-16]. Fang and Wu (2004) reported high concentration of F and Se in tea and corn in bone coal sites in Haoping area, Ziyang County, China [17].

Anjir-tangeh coal washing plant is one of the biggest and oldest coal concentrate producer in the the Cental Alborz Coal Basin [18]. Coal ash content is reduced by physio-chemical processes in this factory. These processes produce a large quantity of liquid and solid wastes that accumulate in waste dump and tailings dam. The excess amounts of the ashes are sent to a pool constructed near the factory. More than 1.5 million tons of waste materials have been piled up in the dumping areas and the sedimentary basins near the coal washing plant so far [19].

Tailings contain quartz, muscovite, montmorillonie, anatase and chamosite [18]. It also contains sulfide minerals, such as pyrite and marcasite. Pyrite and other sulfides in tailings dump are oxidized to sulfate and iron ions [18, 20]. The enrichment factor and geoaccumulation index show that Cd, Hg, Mo and V are enriched in bottom sediments of the coal washing plant and decrease with increasing distance from the factory [21]. Shahhosaini *et al*. (2010 and 2011a) reported that metal contamination in sediments near the discharge mine drainage of tailings dump was significantly high, compared with that in the river sediments, though contamination in the area was not very serious [22, 23].

Based on scientific observation, environmental impact of Anjir-tange coal washing plant is the main reason for low vegetation density around the factory. On the other hand, previous studies suggest that the concentration of some heavy metals is markedly high in soil and water sampled from this area. Moreover, in down tailings dump, plants are fed with the water coming from the tail dump. Therefore, the main objective of this study was to investigate the contamination of native plant species that grow near the coal washing plant.

2. Materials and Methods

2.1. Study area

Anjir–tangeh coal washing plant is located in Mazandaran Province, Iran. It is near to Savadkoh city. Cherat River, a branche of Talar River, flows through this city. The region has humid climate. It lies between longitudes 53˚1΄20″ and 53˚1΄0″E, and latituedes 36˚8΄40″ and 36˚7΄55″N. Karmozd, Karsang and Kiyasar mines supply raw materials to the plant. Central alborz coal mines are located in Shemshak formation on the erosion surface of Elika formation. Shale and sandstone of the Upper Triassic- Middle Jurassic (lias) are the main materials extracted from the mines (Fig. 1).

3. Sampling sites and plant analysis

Figure 2 shows the sampling sites in the study area. Sampling from different plant species was carried out in two seasons (July and November) in 2011. The plants were sampled randomly from the study area (near the Anjir-Tange coal washing plant marked by F in the Fig. 2) and region away from the factory (control area marked by C in the Figure). Plant samples were washed with distilled water and HCl (0.01 N) and dried at 70°C for 48 hours. Dry plants were crushed with a mortar and grind. They were stored in glass containers until the analysis. Each sample of root or shoot organs was separately analyzed for Cr, Cd, Pb, Mo, Cu, Zn, Co and Ni using the ICP-OES method.

4. Results and discussion

The plant families and location of sampling are listed in Table 1. In comparison with the plants in the control area, the diversity of plant grown near the plant was considerably different. The diversity of plant species showed a reduction in their number near the factory and tailings dump. A total of 21 plant species belonging to 15 plant families in the study area were identified. *Equisetum* sp, *Typha latifolia, Trifolium* sp and *Cynodon dactylon* were the abundant of plant species collected in fall, and *Equisetum* sp, *Typha latifolia, Chenopodium* *album L*, *Oxalis* sp and *Polygonom* sp were the abundant plant species collected in summer season. *Trifolium* sp, *Cynodon dactylon*, *Silybum marianum*, *Equisetum* sp, *Chenopodium album*, *Oxalis* sp and *Artemisia absinthium L* were selected for analysis.

5. Concentration of the metals in plants in fall

To determine the concentration of some heavy metals in the plants at the study area, *Trifolium* sp, *Cynodon dactylon* and *Silybum marianum* were analyzed in fall. Table 2 presents heavy metal concentration in the collected plants samples from different locations of coal washing plant and control site. Figure 3 draws a comparison between the concentration of Cr, Co, Cd, Pb, Zn, Cu, Ni and Mo in the three plant species.

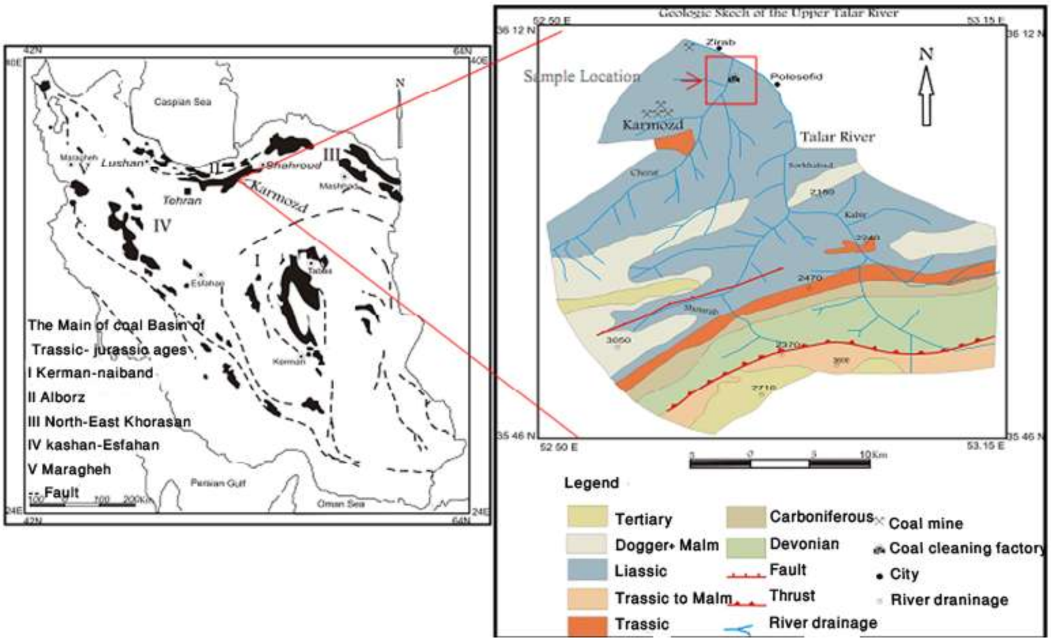

Figure 1. Geologic sketch of the upper Talar River after the 1962 damage [24].

Table 1. Plant species in the study area.

Name	Family	Point of sampling
Equisetum sp	Equistaceae	F2,C5,C3,C2
Chenopodium album L	Chenopodiaceae	F2,C6
Oxalis sp	Oxalidaceae	F3,C4,C2
Artemisia absinthium L	Astraceae	F3,C3
Trifolium sp	Fabaceae	F1,C1
Cynodon dactylon	Poaceae	F1,C1
Silybum marianum	Asteraceae	F2,C1

Table 2. Concentration of the metals in plants collected from tailings and control area in fall.

		Concentration (ppm)							
Plant species	Region	Cr	Co	Cd	Pb	Zn	Cu	Ni	Mo
Trifolium sp	Control area	4.8	4.1	5.7	9.3	43.4	16	5.5	5.6
	Near tailings	7.1	8.9	11.3	28	49	17.3	10.5	18.4
Silybum marianum	Control area	4.6	4	7.8	12	117	21.6	5.1	2.8
	Near tailings	4.1	6	6.9	5.7	67	19.9	5.6	4.1
Cynodon dactylon	Control area	5.1	4.1	6	37	55	14	6	2.1
	Near tailings	5.6	4.9	7.1	37	54.5	18.3	7.1	2.7

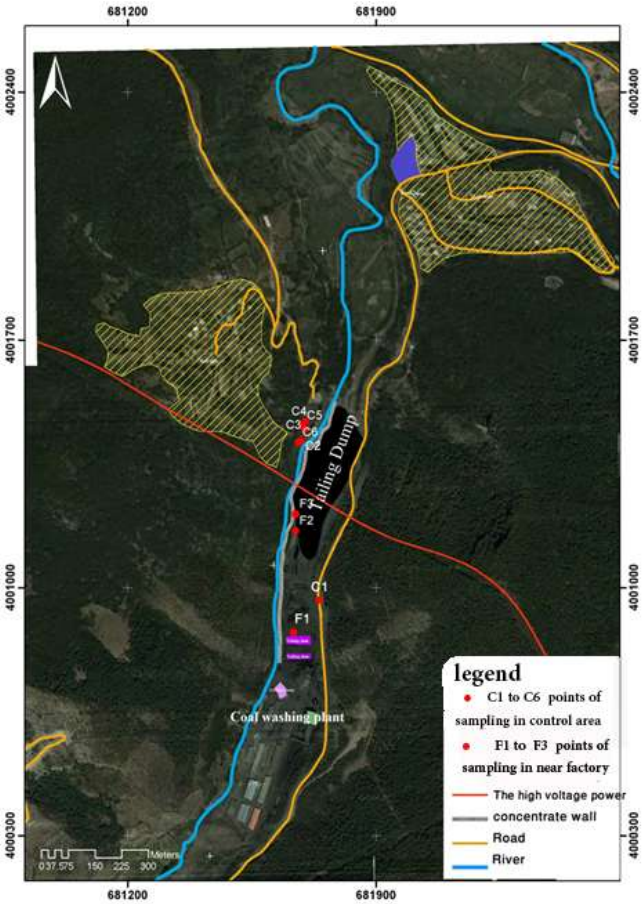

Figure 2. Sampling locations in Anjir Tange coal washing plant [25].

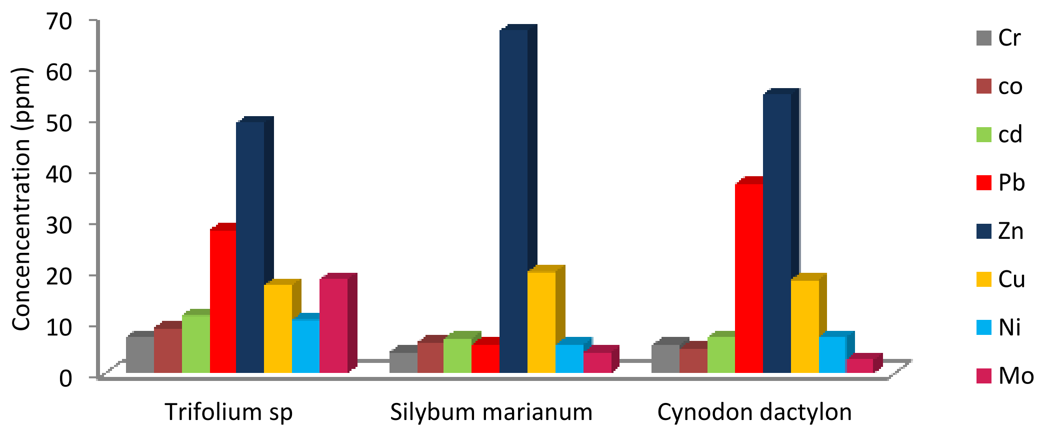

Figure 3. A comparison between metals concentration in the plant species in fall .

Table 3 shows the normal and critical ranges of some heavy metals in plants, compared with those measured in this study. Concentrations of heavy metals in the collected plants are considerably higher than the normal range. However, the concentrations of Zn and Cu in all plants fall into normal range, but the concentration of Mo in *Trifolium* sp lies beyond the critical range. Cadmium concentration was higher than the normal range in all plants. Concentrations of Cr in *Trifolium* sp and *Cynodon dactylon* are higher than the normal range. All of the plants have high levels of Pb concentration; however, *Cynodon dactylon* shows a critical level of Pb concentration. Co concentration is not in a critical range, but all plants have high levels of this metal. *Trifolium* sp has a critical level of

Ni concentration; also, the concentration of this metal is higher than the normal range in other plants (but not as high as the critical level).

T-Student test was used to show the impact of tailings dump on the concentration of the metals in plants in fall. In this test, the average concentration of the two regions were compared. Table 4 provides the results of the T-Student. As given in the table, there is no significent difference between the concentration of metals in plants sampled from control area and those in plants sampled from tailings dump near the factory in fall.

6. Concentration of the metals in plants in summer

The pervious plants collected in fall showed that concentrations of Cr, Cd and Pb were high; thus, these metals were selected to investigate in plants sampled in the following summer.

Four plant species, *Equisetum* sp, *Chenopodium album, Oxalis* sp and *Artemisia absinthium L*, were selected to detect the concentration of Pb, Cd and Cr in summer. The results of analysis of plants collected in summer are given in Table 5. The concentrations of Cr, Cd and Pb are in normal ranges in all plants investigated in the control and tailings areas.

To test the impact of tailings dump and plant species on the concentration of metals in plants in summer, the analysis of variance (ANOVA) was performed (Table 6). According to Table 6, the impact of tailings dump on the concentration of Cr and Pb in plants is not significant; though it is significant ($P \leq 0.05$) on Cd concentration.

The effect of plant species on the concentrations of Cr and Cd is significant ($P \leq 0.01$); however, it is not significant on Pb concentration. The interaction of tailings dump and plants species has no significant effect on the concentration of metals in plant species (Table 6).

Table 3. Normal and critical ranges of the metals in plants and the levels measured in this study.

Elements	Concentration in the studied plants ($\mu g g^{-1}$)	Normal ranges ($\mu g g^{-1}$)	Critical ranges ($\mu g g^{-1}$)	References
Cd	6.9-11.3	0.1-2.4	5-30	[26-28]
Cr	4.1-7.1	0.2-5	5-30	[26, 27]
Co	4.9-8.9	0.02-1	15-50	[26]
Pb	5.7-37	0.2-5	30-300	[26-28, 30]
Cu	17.3-19.9	5-20	20-100	[26,28]
Ni	5.6-10.5	0.02-5	10-100	[26]
Mo	2.7-18.4	0.03-5	10-50	[26, 31]
Zn	49-67	27-100	100-400	[26-28, 31]

Table 4. Concentration of the metals in plants collected from near the factory and control area in fall.

	Means of concentration (ppm)							
Region of sampling	Mo	Ni	Zn	Cu	Co	Pb	Cd	Cr
Contol area	3.5	5.53	71.8	17.2	4.06	19.43	6.5	4.83
Near tailings	8.4	7.73	56.83	18.5	6.6	23.56	8.43	5.6
t calculated	1.24	1.56	0.85	0.75	2.14	0.55	1.00	0.935
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The results showed that metal concentrations in plants in the vicinity of tailings dump were higher than those in the control plants. The concentrations of Pb and Cr in the plants exhibited no significant differences in the two locations. Yet, Cd concentration in plants near the tailings was significantly higher than that in the control plants (Fig. 4).

Table 5. Concentration of metals in plants in summer.

			Concentration (ppm)		
Spcies plants	Region of sampling	Repeat of sampling	Pb	Cd	Cr
Artemisia absinthium L	Control area	R1	0.97	0.129	0.82
		R2	1	0.077	0.48
		R3	1.86	0.18	0.89
	Near tailings	R1	1.15	0.23	1.04
		R2	0.39	0.3	0.54
		R3	3.12	0.22	0.91
Equisetum sp		R1	0.69	0.11	0.88
	Control area	R2	1.74	0.115	0.5
		R3	1.215	0.12	0.6
		R1	0.86	0.194	0.67
	Near tailings	R2	0.85	0.13	0.49
		R3	1.95	0.12	0.85
Oxalis sp		R1	1.47	0.17	0.45
	Control area	R2	0.8	0.33	0.6
		R3	0.75	0.47	0.73
		R1	1.51	0.73	0.748
	Near tailings	R2	0.93	0.495	0.54
		R3	1.37	0.26	0.88
Chenopodium album	Control area	R1	0.18	0.015	0.25
		R2	0.16	0.096	0.336
		R3	0.17	0.03	0.3
	Near tailings	R1	1.03	0.23	0.388
		R2	0.775	0.18	0.25
		R3	0.48	0.29	0.28

Table 6. The impact of plant species and tailings dump on the concentration of the metals in plant species in summer.

		Mean Square		
	df	Pb	Cr	Cd
Plant species	3	1.027^{ns}	0.259^{**}	0.101^{**}
Tailings dump	1	0.478^{ns}	0.023^{ns}	0.098^{*}
Tailings dump× plant species	3	0.084^{ns}	0.005^{ns}	0.007^{ns}
Error	16	0.405	0.030	0.011

*and**Indicates a statistically significant effects in levels of 5 and 1 percents, respectively.

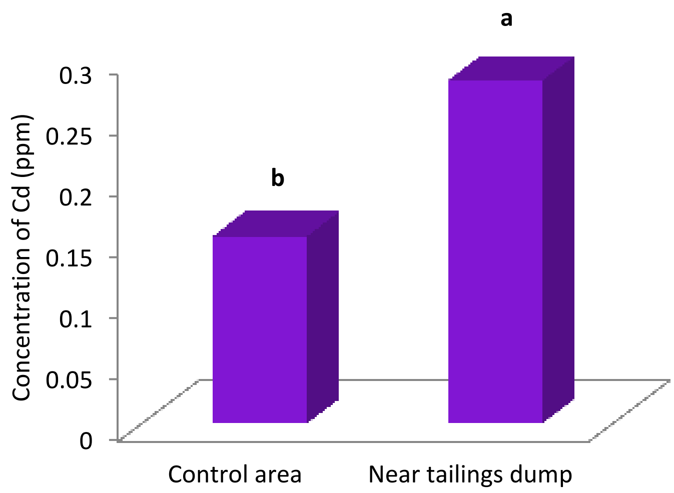

Figure 4. Average concentration of Cd in control plants and plants near the tailings in summer.

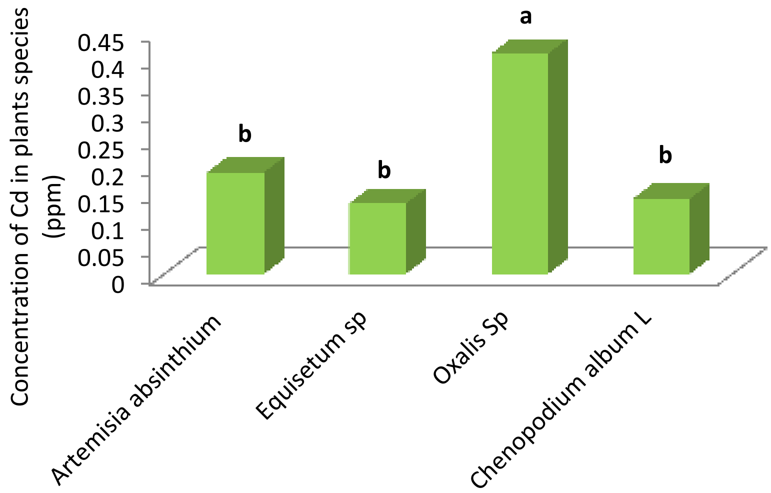

Figure 5. Average concentration of Cd in the studied plant species in summer.

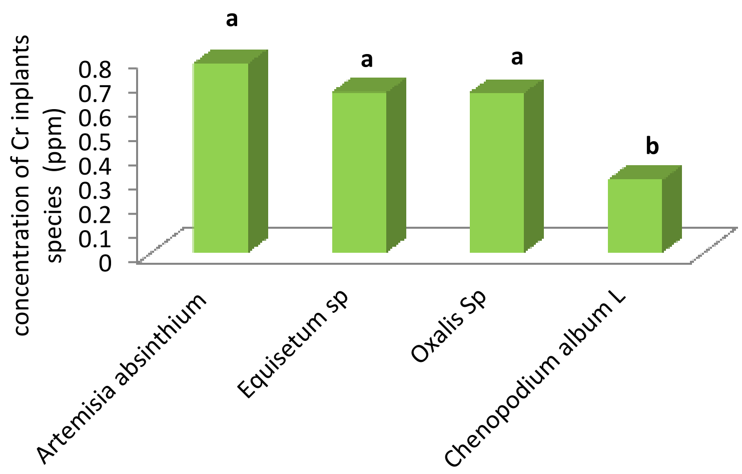

Figure 6. Average concentration of Cr in the studied plant species in summer.

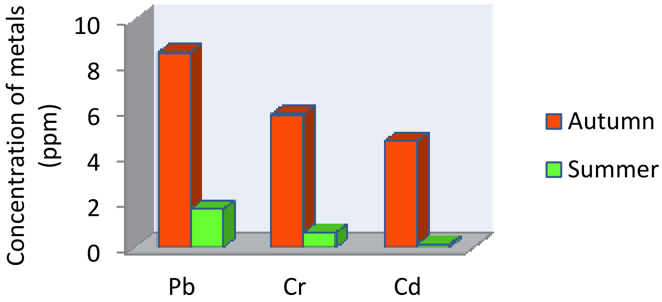

Figure 7. Concentrations of Pb, Cd and Cr in plant species sampled in fall and summer.

The mean value of metal concentrations in plant species is shown in Figures 5 and 6.As illustrated in Figure 6, Cadmium concentration is significantly higher in *Oxalis* Sp than in other plants. *Chenopodium album L* has the lowest concentration of Cr. and the concentration of this metal is not significantly different in other plants.

7. Impact of season in concentration of metals in plants

A comparison was drawn between the two seasons, suggesting that the concentration of metals in plants in fall was higher than that in summer (Figure 7). This may be due to longer metal accumulation by shoots and roots of plant species.

8. Conclusion

The efficiency of Anjir-tangeh coal washing plant is low and coal is the fundamental constituent of the tailings dump. Therefore, the concentration of elements in plants around the tailings dump should be dependent on the coal geochemistry. It should be mentioned that based on the results of Gholipoor *et al.* (2010) study, the mean content of trace elements in Karmozd coal differs from the mean content of trace elements in the coal obtained from other places around the world [32].

The sampling points at the study area have the same climatic, edaphic and physiographic features. Thus, the difference in the chemical composition of the similar plant species can be attributed to coal washing activities which reduces plant diversity near the plant. This is in agreement with the findings of Das Gupta (1999), Baig (1992), Jha and Singh (1990) [33-35]. The plant has caused massive damage to the local environment and plant species.

However, this study showed that human activity in coal washing factory does not have a significant effect on the concentration of metals in the plants sampled in fall. Nevertheless, Cd concentration in plants near the tailings was higher than that in the control area in summer.

Plant species have different abilities for metal uptake from contaminated soils [36]. In this study, the concentrations of Cr and Cd, measured in different plant species, were significantly different. In summer, *Oxalis* Sp had the highest ability for uptake of Cd, but *Chenopodium album* showed the lowest ability for absorption of Cr. On the other hand, season proved to be an effective factor in the uptake of metals by plants. Metal concentration in plants was considerably higher in fall than in summer.

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