Research Journal of Environmental Sciences

ISSN 1819-3412

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Environmental Sciences 3 (5): 581-587, 2009
ISSN 1819-3412

Translocation and Bioaccumulation of Trace Metals in Desert Plants of Kuwait Governorates

Abdul H. Bu-Olayan and Bivin V. Thomas
Department of Chemistry, Faculty of Science, Kuwait University,
P.O. Box 5969, Safat-13060, Kuwait

Abstract: Recent industrialization showed possible trace metals pollution impact in the Kuwait arid ecosystem. Desert plants that were distributed in the six Kuwait Governorate areas representing the residential, industrial and recreational sites (GI-VI) were assessed for trace metals. Observation showed high trace metal concentrations in the sequence of leaves> soil> shoot> root irrespective of the species and areas, respectively. *Chrozophora tinctoria* showed higher trace metals concentration than the other species. Samples in GII showed high trace metals levels among the six Governorates indicating the significance of pollution due to the recent urban development and rise in population. Metal-wise analysis revealed high metals levels in the sequence of Al (14.16 $\mu g\ g^{-1}$) > Cu (10.71 $\mu g\ g^{-1}$) > Ni (4.83 $\mu g\ g^{-1}$)> Fe (4.60 $\mu g\ g^{-1}$)>Pb (2.89 $\mu g\ g^{-1}$)>V (2.52 $\mu g\ g^{-1}$). Trace metals Translocation Factor (TF) and Bioaccumulation factor (BAF) in all the plants were >1 thus labeling these plants as trace metals accumulators. Pearson's correlation coefficient on species-wise and metal-wise analysis revealed significance between TF and BAF, respectively. Thus, trace metals sequestration from the soil to these plants characterized them as trace metals pollution indicators.

Key words: Trace metals levels, bio-indicator plants, air pollution

INTRODUCTION

Environmental pollution with toxic metals has increased dramatically due to rapid industrialization and surge in population (Al-Kateeb and Leilah, 2005). The main source of pollution are fossil fuels, fumes from motor vehicles, industrial production processes, the use of industrial products and fires, in some areas, natural sources by air blown dusts, vegetation and sea salt sprays, wild fires, volcanoes, landfill leachates, fertilizers, sewage, discharges from the power and treatment plants (Bargagli, 1998; Yoon *et al*., 2006; Yusuf and Oluwole, 2009). Trace metals deposition in plants from anthropogenic sources has increased the attention on inorganic pollution and established plants as passive bio-monitors (Wittig, 1993; Monaci *et al*., 2000). A variety of plants species are used as biological monitors since, they have a tendency to assimilate metals from the surrounding environment (Djingova *et al*., 1993; Bargagli, 1998; Kadukova *et al*., 2008). With the increase in global metals contamination, plants process metals, might provide efficient and ecologically sound approaches to sequestration and removal through leaves, stem and roots. Their concentrations can be correlated with their surrounding soil (Keane *et al*., 2001). In the desert, many plants were found to be biological indicators with broad specificity to inorganic pollutants (Simon *et al*., 1996). Metals sequestered by these plants may be transferred through trophic links from detritus communities to secondary and tertiary consumers and thus lead to the total contamination of the arid ecosystem (Lyngby and Brix, 1989; Sinegani and Ebrahimi, 2007). Metal toxicity was found to have significant relationship with

---

Corresponding Author: Abdul H. Bu-Olayan, Department of Chemistry, Faculty of Science, Kuwait University, P.O. Box 5969, Safat-13060, Kuwait Tel: +965-24987075 Fax: +965-24816482

factors controlling metal tolerance, including available uptake sites, chemical interaction and ionic speciation. Many plants that accumulate >1000 or >10000 mg kg^{-1} of trace metals are categorized as metals hyper accumulators (Baker and Brooks, 1989). Ma *et al.* (2001), Roselli *et al.* (2003), Yoon *et al.* (2006) and Sinegani and Ebrahimi (2007) observed significant trace metals mobilization between the plant parts above and below the surface of the soil with translocation factor (TF)>1. Most plants translocate inorganic and nutrient constituents from roots to leaves (Roselli *et al.*, 2003).

Based on the above studies, the objective of the present study was to determine (1) the trace metal concentrations in the leaves, stem and roots of six desert plants in relation to its surrounding soil, (2) Bio-accumulation factor (BAF) and Translocation Factor (TF) and its interrelationship in six plants and (3) in six Kuwaiti Governorate areas.

MATERIALS AND METHODS

Study Sites

Six Kuwait Governorate areas were chosen for our study are namely, (a) G-I (Jahra): Situated at the North of Kuwait that comprises of residential, industrial, vegetation and desert areas and significant with thermal, power, desalination and water treatment plants, (b) G-II (Capital/Kuwait City): The Central Kuwait zone with industrial and residential areas significant for its business centers, domestic wastewater outfalls, (c) G-III (Hawalli): Known for its business activities and residential areas (d) G-IV (Farwaniya): With densely populated residential areas (e) G-V (Mubarek Al-Kabeer): With moderately populated residential and recreational activities and (f) G-VI (Ahmedi): The Southern Region of Kuwait with oil fields, allied industries, scanty residential and green house vegetation sites (Fig. 1).

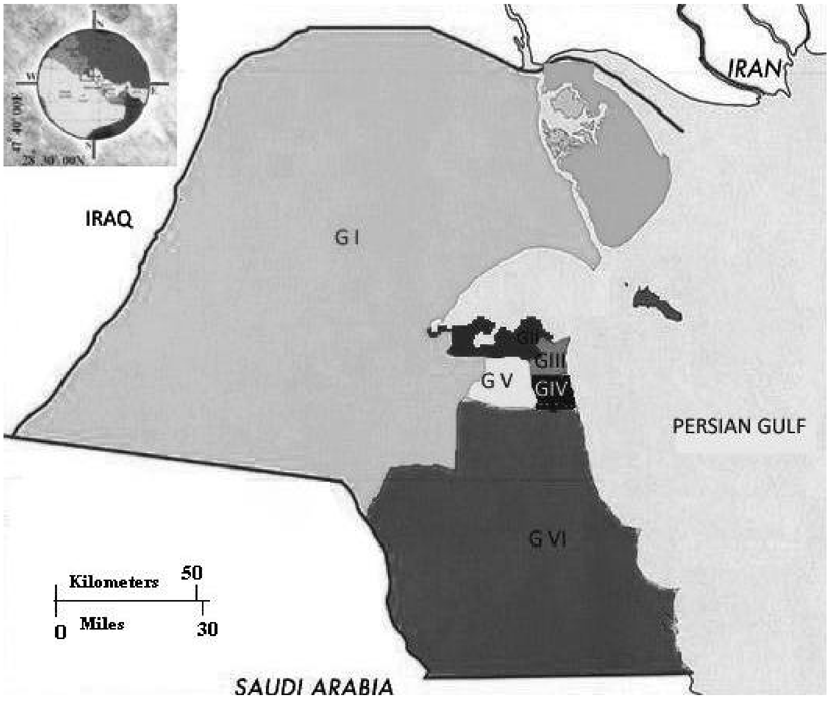

Fig. 1: Sampling sites of desert plants in the Kuwait Governorates GI-GVI: Jahra, Kuwait City, Hawalli, Farwaniya, Mubarek Al-Kabeer and Ahmedi

Sampling

Desert plants (replicates: 10 Nos.) such as *Malva parviflora*, *Suaeda aegyptiaca*, *Chrozophora tinctoria*, *Fagonia bruguieri*, *Gynandriris sisyrinchium* and *Ducrosia anethifolia* were collected from six Kuwait Governorate areas (Fig. 1) from October 2006 to December 2008. These plants were collected based on their orientation towards the wind and leeward direction following the methodology of Sinegani and Ebrahimi (2007). Samples were thoroughly rinsed in deionized distilled water to remove the dust and soil. They were collected in sterile polyethylene labeled (Fischer brand, US) zipper bags (34×30 cm × 0.3 mm), stored in Thermo Cole box and transported to the lab. They were stored at -4°C before analysis. The thawed plant parts such as leaves, stem and roots were cut into small pieces (5 cm) placed in a sterile Petri-dish (9 cm).

Soil samples (100 g) below 5 cm from the surface, adjoining each plant species in the Kuwait Governorate areas were scooped and collected in sterile polyethylene containers and transported to the laboratory (Keane *et al*., 2001).

Replicate plant and soil samples (5 and 100 g) from each area were dried until constant weight at 50°C in an oven (GallenKamp II), respectively. Dried plants and soil were powdered in the Agate mortar (Reutch), homogenized and sieved in 1.0 mm sieve mesh and stored in sterile vials (Djingova *et al*., 1993; Keane *et al*., 2001). Samples (0.2 g) were used for trace metal analysis.

Trace Metal Analysis

Plant leaves, stem and roots and soil samples were predigested in HNO_3: HCl (Aristar grade v/v ratio of 3:1) in a polystyrene sterile centrifuge tube and then waited overnight. The soil samples were treated further with 1% HF for the complete mineralization and digestion (Bu-Olayan and Thomas 2002). The samples diluted in de-ionized water (50 mL) and digested in an automatic microwave digester (Spectroprep CEM) was measured in the Analytik Jena, Zeenit-650 to determine the metals concentration.

Trace metals translocation in these plants from shoot to root was measured using TF which is given below:

$$\mathrm{TF} = C_s/C_r \tag{1}$$

where, C_s and C_r are metal concentrations ($\mu g\ g^{-1}$) in the shoot and root, respectively.

Wherein, TF>1 indicates that the plant translocate metals effectively from root to the shoot (Baker and Brooks, 1989). Further, trace metals BAF in these plants was determined by calculating the ratio of metal concentration in the aerial parts to that of the soil as given below:

$$\mathrm{BAF} = C_p/C_{so} \tag{2}$$

where, C_p and C_{so} are metal concentrations in aerial parts of the plant ($\mu g\ g^{-1}$) and in soil ($\mu g\ g^{-1}$), respectively.

BAF was categorized further as hyper-accumulators, accumulator and excluder to those samples which accumulated metals $>10\ \mu g\ g^{-1}$, >1 and <1, respectively (Ma *et al*., 2001).

Quality assurance employing replicates, standard trace metals (ICP grade), blanks and Standard Reference Material: Orchard leaves (SRM 1571) for desert plants and Montana soil (SRM 2711) for soil samples from National Institute Standard Technology (NIST) assessed the precision of the instrument. Recoveries of samples (98±2%) in agreement with certified values were considered as a part of quality control. Pearson's correlation coefficient was used to show correlation significance of trace metals concentrations among studied variables.

RESULTS

Trace Metal Concentrations in Desert Plants and Soil

The total mean trace metal concentrations were in the sequence of *C. tinctoria* (8.25 $\mu g\ g^{-1}$), *M. parviflora* (7.96 $\mu g\ g^{-1}$), *S. aegyptiaca* (6.12 $\mu g\ g^{-1}$), *G. sisyrinchium* (6.06 $\mu g\ g^{-1}$) and *D. anethifolia* (5.82 $\mu g\ g^{-1}$), *F. bruguieri* (5.51 $\mu g\ g^{-1}$) (Table 1). Governorate-wise, the mean metal concentrations were observed in the sequence of GII>GI>GVI>GIII>GIV>GV (Table 2).

The mean trace metal concentrations in the desert plant leaves, shoot and roots were 7.36, 6.72 and 5.78 $\mu g\ g^{-1}$, respectively (Table 3). The trace metal concentration in soil collected from the surrounding sampled plants was measured as 6.78 $\mu g\ g^{-1}$. Further, high trace metals concentration was observed in soil collected near *C. tinctoria* (7.98 $\mu g\ g^{-1}$) followed by *M. parviflora* (7.91 $\mu g\ g^{-1}$) > *S. aegyptiaca* (6.67 $\mu g\ g^{-1}$) > *G. sisyrinchium* (6.59 $\mu g\ g^{-1}$) > *D. anethifolia* (5.92 $\mu g\ g^{-1}$) > *F. bruguieri* (5.63 $\mu g\ g^{-1}$). The overall mean trace metal levels in the three parts of these plants with soil samples showed similar sequence as observed in Table 3.

Governorate wise analysis showed the three parts of the sampled plants with trace metal concentrations in the sequence of GII> GI>GVI>GIII>GIV>GV (Table 4).

Metals-wise analysis showed mean trace metal concentration in Al (14.16 $\mu g\ g^{-1}$) followed by Cu (10.71 $\mu g\ g^{-1}$) > Ni (4.83 $\mu g\ g^{-1}$) >Fe (4.60 $\mu g\ g^{-1}$)>Pb (2.89 $\mu g\ g^{-1}$) >V (2.52 $\mu g\ g^{-1}$) (Table 5).

Table 1: Total mean metals levels ($\mu g\ g^{-1}$) in the desert plant species of Kuwait Governorates

Species	Mean metal levels
SP1	7.96±0.99
SP2	5.51±0.36
SP3	6.12±0.35
SP4	5.82±0.43
SP5	8.25±0.46
SP6	6.06±0.35

Table 2: Mean metals levels ($\mu g\ g^{-1}$) in each desert plants from the six Kuwait Governorates

Governorates	SP_1	SP_2	SP_3	SP_4	SP_5	SP_6
GI	8.75±1.17	5.78±0.40	6.41±0.44	6.08±0.42	8.53±0.98	6.36±0.48
GII	9.33±1.98	5.94±0.56	6.50±0.45	6.38±0.49	8.90±1.11	6.45±0.44
GIII	7.97±0.83	5.57±0.37	6.12±0.37	5.81±0.41	8.24±0.95	6.09±0.30
GIV	7.11±0.62	5.12±0.34	5.78±0.31	5.49±0.30	7.91±0.58	5.74±0.39
GV	6.63±0.60	5.03±0.30	5.62±0.32	5.16±0.28	7.59±0.50	5.54±0.29
GVI	7.97±0.95	5.65±0.38	6.27±0.42	5.98±0.35	8.33±0.92	6.16±0.33
Mean	7.96±0.99	5.51±0.36	6.12±0.35	5.82±0.43	8.25±0.46	6.06±0.35

GI-GVI: Kuwait Governorates; SP1-SP6: *Malva* sp., *Fagonia* sp., *Suaeda* sp., *Ducrosia* sp., *Chrozophora* sp. and *Gynandris* sp.

Table 3: Species-wise mean metal levels ($\mu g\ g^{-1}$) in the desert plant parts and soil from Kuwait Governorates

Parts	SP_1	SP_2	SP_3	SP_4	SP_5	SP_6
Leaves	8.86±1.08	5.87±0.73	6.78±0.77	6.12±0.72	9.56±1.95	6.97±0.78
Shoot	7.83±0.83	5.43±0.63	6.65±0.75	5.89±0.70	7.94±0.85	6.56±0.72
Root	7.19±0.81	5.24±0.62	4.93±0.60	5.44±0.65	7.25±0.80	4.65±0.56
Soil	7.91±0.84	5.63±0.72	6.67±0.76	5.92±0.71	7.98±0.87	6.59±0.73
Mean	7.95±0.68	5.54±0.27	6.26±0.88	5.84±0.28	8.18±0.97	6.19±1.04

SP1-SP6: *Malva* sp., *Fagonia* sp., *Suaeda* sp., *Ducrosia* sp., *Chrozophora* sp. and *Gynandris* sp.

Table 4: Governorate-wise mean metal levels ($\mu g\ g^{-1}$) in the desert plant parts and soil

Governorates	Leaves	Shoot	Root	Soil
GI	7.60±0.79	7.12±0.72	6.22±0.54	6.73±0.65
GII	7.65±0.80	7.41±0.78	6.70±0.63	7.80±0.83
GIII	7.29±0.74	6.71±0.63	5.90±0.48	6.35±0.58
GIV	7.19±0.73	6.30±0.52	5.08±0.42	6.01±0.51
GV	7.02±0.70	5.96±0.48	4.82±0.38	6.56±0.60
GVI	7.38±0.75	6.84±0.68	5.98±0.49	7.21±0.74
Mean	7.36±0.24	6.72±0.53	5.78±0.70	6.78±0.64

GI-GVI: Kuwait Governorates

Table 5: Metal-wise levels (µg g^{-1}) in each species of Kuwait desert plants

Species	Al	Fe	Cu	Pb	V	Ni
SP$_1$	16.18±2.58	5.56±0.84	12.93±2.21	3.84±0.92	3.35±0.87	5.91±1.16
SP$_2$	12.79±2.38	4.09±0.35	8.85±1.12	2.28±0.32	1.98±0.19	3.09±0.29
SP$_3$	13.01±2.45	4.25±0.38	10.12±2.14	2.48±0.29	2.19±0.27	4.64±0.50
SP$_4$	12.84±1.85	4.13±0.36	8.93±1.04	2.37±0.25	2.03±0.22	4.59±0.48
SP$_5$	17.16±2.73	5.41±0.76	13.44±2.38	3.96±0.48	3.43±0.43	6.12±1.19
SP$_6$	12.98±1.87	4.19±0.37	9.99±2.22	2.41±0.37	2.15±0.29	4.62±0.48
Mean	14.16±1.96	4.60±0.68	10.71±1.99	2.89±0.78	2.52±0.67	4.83±1.09

SP$_1$-SP$_6$: *Malva* sp., *Fagonia* sp., *Suaeda* sp., *Ducrosia* sp., *Chrozophora* sp. and *Gynandris* sp.

Table 6: Mean metal wise levels (µg g^{-1}) in desert plants from each Kuwait Governorate

Governorates	Al	Fe	Cu	Pb	V	Ni
GI	14.81±2.50	4.90±0.55	11.17±2.12	3.13±0.36	2.77±0.30	5.12±0.58
GII	15.09±2.53	5.26±0.61	11.76±2.15	3.24±0.38	2.87±0.33	5.27±0.61
GIII	14.37±2.48	4.76±0.51	10.54±1.99	2.83±0.32	2.46±0.21	4.83±0.52
GIV	13.47±2.46	4.00±0.42	10.24±1.93	2.63±0.27	2.31±0.21	4.49±0.48
GV	12.85±2.49	3.82±0.40	9.99±1.91	2.52±0.24	2.12±0.20	4.26±0.19
GVI	14.35±2.47	4.88±0.53	10.57±2.02	2.98±0.34	2.59±0.26	4.99±0.55
Mean	14.16±0.84	4.60±0.56	10.71±0.64	2.89±0.28	2.52±0.28	4.83±0.38

GI-GVI: Kuwait Governorates

Table 7: Translocation and bioaccumulation factor for six desert plants of Kuwait

Factor	*Malva* sp.	*Fagonia* sp.	*Suaeda* sp.	*Ducrosia* sp.	*Chrozophora* sp.	*Gynandris* sp.
Translocation	1.090	1.040	1.350	1.080	1.100	1.410
BAF	1.232	1.120	1.375	1.125	1.319	1.499

Table 8: Trace metals translocation and bioaccumulation factor on Kuwaiti desert plants

Factor	Al	Fe	Cu	Pb	V	Ni
Translocation	1.02	1.01	1.01	0.99	1.01	1.01
BAF	1.10	1.07	1.02	1.01	1.02	1.00

Species-wise analysis revealed high trace metals concentrations in *C. tinctoria* (17.16 µg g^{-1}). The mean concentration of each trace metal in each Governorate (Table 6) showed similar trace metals concentrations in sequence to that of the sequence observed in Table 2.

Bioaccumulation Factor (BAF) and Translocation Factor (TF) in the Samples

TF in all the six desert plants were higher than 1. TF and BAF were observed in the sequence of *Gynandriris sisyrinchium*>*Suaeda aegyptiaca*>*Chrozophora tinctoria*>Malva *parviflora*>*Ducrosia anethifolia*>*Fagonia bruguieri* (Table 7, 8). Results showed the metals concentrations <1000 µg kg^{-1} in all the investigated samples. Findings indicated TF < BAF in metals and species wise analysis (Table 7, 8).

DISCUSSION

Among the six sampled desert plants (Table 1) high trace metals concentrations in *C. tinctoria* attributes to their rough surface leaves that allow deposition of dust particles that contain inorganic pollutants (Yoon *et al*., 2006; Sinegani and Ebrahimi, 2007). These plants are able to limit competition from other plants by taking up inorganic constituents from deep ground water, accumulating it in their foliage and from there depositing it in the surface soil where it builds up concentrations temporarily detrimental to other plants (Al-Kateeb and Leilah, 2005; Kadukova *et al*., 2008).

Table 2 showed higher trace metal concentrations in Governorate (GII) than the other five sampled sites. High trace metals concentrations in this area attribute to the congested industrial and residential areas and support the findings of Bu-Olayan and Thomas (2002). Leaves revealed higher trace metal concentrations than shoot and roots irrespective of the sampled species (Table 3). This could be attributed to (1) the larger exposure area of the leaves than the other parts to wind action, (2) surface adsorption of particulate matter and (3) high rate of assimilation of trace metals from the environment agreed with the findings of Keane *et al*. (2001) and Al-Kateeb and Leilah (2005).

Trace metal concentrations in soil was comparatively higher than in roots and shoots but lower than that of the leaves in the sampled plants (Table 3). This indicates the mobilization of trace metals from soil through the roots to the shoot, leaves of these plants, which was also found in the literature (Baker and Brooks, 1989; Djingova *et al*., 1993; Keane *et al*., 2001; Sinegani and Ebrahimi, 2007). However, this phenomenon of metals levels in soil with parts of the plants was in contrary to the findings of Bu-Olayan and Thomas (2002) in date palms. This could be attributed to the variations observed in the (a) morphological, (b) absorption area, (c) phyllotaxis of the leaves and (d) effect of different metals concentrations analyzed to that of the present study. Table 4 indicated Governorate wise analysis with similar sequence of trace metals concentrations (Table 2). Low trace metal concentrations in GV attributes to restricted human interferences, allied industries and efficient air monitoring system and supports the earlier findings (Wittig, 1993; Bargagli, 1998; Monaci *et al*., 2000). Species wise study showed high Al concentrations among the other metals studied (Table 5). This may be attributed to the rapid industrialization, anthropogenic resources and frequent dust storms in this arid ecosystem. Comparatively, Fe concentration was lower than the concentration of the other metals due to their assimilation in plants (Djingova *et al*., 1993). Meanwhile, Pb and V showed low concentrations that attributes to their immobility of effective translocation in the plants (Simon *et al*., 1996; Yoon *et al*., 2006). Species-wise analysis showed high trace metals concentration in *C. tinctoria* than the other species. These species are observed especially in wastewater contaminated outlets that are enriched in high trace metals concentrations. Thus, this plant could be used for the assessment of individual biomarker of inorganic pollution.

The mean Governorate-wise analysis showed high trace metals concentration in GII when compared to the metals concentrations from the other Governorate samples (Table 6).

The sampled desert plants showed both TF and BAF >1 (Table 7, 8) and hence, they could be labeled as accumulators of pollution as described earlier (Lyngby and Brix, 1989; Baker and Brooks, 1989). However, these samples showed metal concentrations < 1000 $\mu g\ kg^{-1}$ and thus, none could be classified as hyper-accumulators (Baker and Brooks, 1989; Ma *et al*., 2001). Tolerance limits of these species to trace metals accumulation estimation through BAF and TF could be used in phytoremediation process (Roselli *et al*., 2003; Sinegani and Ebrahimi, 2007). Pearson's correlation revealed that high correlation ($R^2 = 0.89$) was found between TF and BAF for species wise. However, metal wise correlation between TF and BAF was found less correlated ($R^2 = 0.58$) than species wise TF and BAF. This suggests that each type of plant follow a specific pattern to metals sequestration that varies because of environmental factors and metals accumulation (Ma *et al*., 2001; Rosselli, 2003; Yoon *et al*., 2006).

CONCLUSION

The present investigation revealed that these plants could be used as potential tool: (1) to study the trace metals pollution levels in each Governorate, (2) to determine the interrelationship between BAF and TF and (3) for site specific studies to inorganic pollutants in the arid environment.

ACKNOWLEDGMENTS

Authors are thankful to the Kuwait Foundation for the Advancement of Sciences, for the financial support of our project (KFAS-2006-1401-02). Authors are also thankful to the the Research Administration and SAF (GS 01/01, GS01/05) Kuwait University, for their support and sample analysis, respectively.

REFERENCES

Al-Khateeb, S.A. and A.A. Leilah, 2005. Heavy metals accumulation in the natural vegetation of Eastern Province of Saudi Arabia. J. Biological Sci., 5: 707-712.

Baker, A.J.M. and R.R. Brooks, 1989. Terrestrial higher plants which hyper accumulate metallic elements-a review of their distribution, ecology and phytochemistry. Biorecovery, 1: 81-26.

Bargagli, R., 1998. Trace Elements in Terrestrial Plants: An Ecophysiological Approach to Biomonitoring and Biorecovery. Springer Verlag, Berlin.

Bu-Olayan, A.H. and B.V. Thomas, 2002. Bio monitoring studies on the effect of lead levels in date palm (*Phoenix dactylifera*) in the arid ecosystem of Kuwait. J. Arid Environ., 51: 133-139.

Djingova, R., I. Kuleff and N. Andreev, 1993. Comparison of the ability of several vascular plants to reflect environmental pollution. Chemosphere, 27: 1385-1396.

Kadukova, J., E. Manousaki and N. Kalogerakis, 2008. Pb and Cd accumulation and phyto-excretion by salt Cedar (*Tamarix smyrnensis Bunge*). Int. J. Phytomed., 10: 31-46.

Keane, B., M.H. Collier, J.R. Shann and S.H. Rogstad, 2001. Metal contents of dandelion (*Taraxacum officinale*) leaves in relation to soil contamination and airborne particulate matter. Sci. Total Environ., 281: 63-78.

Lyngby, J.E. and H. Brix, 1989. Heavy metals in Eelgrass (*Zostera marina* L.) during growth and decomposition. Hydrobiology, 176: 189-196.

Ma, L.Q., K.M. Komar, C. Tu, W. Zhang, Y. Cai and E.D. Kenelly, 2001. A fern that hyper accumulates arsenic. Nature, 409: 579-582.

Monaci, F., F. Moni, E. Lanciotti, D. Grechi and R. Bargagli, 2000. Biomonitoring of air borne metals in urban environments: New traces of vehicle emission, in place of lead. Environ. Pollut., 107: 321-327.

Rosselli, W., C. Keller and K. Boschi, 2003. Phytoextraction capacity of trees growing on metal contaminated soil. Plant Soil, 256: 265-272.

Simon, L., H.W. Martin and D.C. Adriano, 1996. Chicory (*Cichorium intybus* L.) and Dandelion (*Taraxacum officinale* Web.) as phyto indicators of cadmium contamination. Water Air Soil Pollut., 91: 351-362.

Sinegani, A.A.S. and P. Ebrahimi, 2007. The potential of Razan-Hamadan highway indigenous plant species for the phytoremediation of lead contaminated land. Soil Environ., 26: 10-14.

Wittig, R., 1993. General Aspects of Biomonitoring Heavy Metals by Plants. In: Plants as Biomonitors, Market B. (Ed.). VCH Verlagsgesellschaft, Weinheim, Germany, pp: 3-27.

Yoon, J., X. Cao, Q. Zhou and Q.M. Lena, 2006. Accumulation of Pb, Cu and Zn in native plants growing on a contaminated Florida site. Sci. Totel Environ., 368: 456-464.

Yusuf, K.A. and S.O. Oluwole, 2009. Heavy Metal (Cu, Zn, Pb) contamination of vegetables in urban city: A case study in Lagos. Res. J. Environ. Sci., 30: 292-298.