Journal

J. Biol. Chem.
Environ. Sci., 2010,
Vol. 5(3): 219-238
www.acepsag.org

ANATOMICAL CHANGES DUE TO UPTAKE AND ACCUMULATION OF METALS IN METALLOPHYTE *TAMARIX NILOTICA* (EHRENB.)

Reham K. I. Badwy, Eman A. Diab

Desert Research Center, Plant Ecology Department, Environmental pollution Unit, Cairo, Egypt

ABSTRACT

A quantitative assessment was made of metal contamination levels and anatomical changes of *Tamarix nilotica* (Ehrenb.) growing in Suez Gulf area of Egypt where gas-and oil extracting and processing are concentrated and polluting the surrounding soils with their wastes without any protection system. Concentrations of Al, B, Cd, Co, Cr, Cu, Fe, Mo, Ni, V and Zn were measured in soils and in *Tamarix nilotica* plant organs i.e, root, stem and leaf. Correlation coefficients between DTPA-extractable Cd & Cu & Fe are significant positively correlated with ECe (r^2=0.998, 0.999 and 0.999; respectively); Extractable B and Ni are also significant positively correlated with O.M. % by (r^2=1 and 0.998, respectively). While extractable Cr and Cu being significant negatively correlated with pH (r^2= 0.999 and 0.995; respectively). Elements were concentrated in the leaves of plant relative to the stems and roots. All plant parts had high levels of heavy metals content in comparison with those of plant parts in control site. Noticeable anatomical changes of stems and leaves were induced due to uptake of heavy metals.

The results of this investigation provide strong evidence that *Tamarix nilotica* acts as an ideal plant to be used in metal phytoextraction processes.

Key words: metal pollution, *Tamarix nilotica* (Ehrenb.), anatomical changes, DTPA-extractable metals, Suez Gulf.

INTRODUCTION

Tamarix nilotica (Ehrenb.) Bunge. (Family: *Tamaricaceae*; Arabic name: Tarfa or Abal) are shrubs form dense thickets (Pulford et al., 1992), it has deep rooted, facultative phreatophytes that can reproduce vegetativity from roots or crowns if the above-ground parts are damaged, or from the copious production of small wind-blown or water-transported seeds. A major environmental concern due to dispersal of industrial and urban wastes generated by human anthropological was the contamination of soil. Controlled and uncontrolled disposal of waste, accidental and process spillage, mining and smelting of metalliferous ores, sewage sludge application to agricultural soils are responsible for the migration of contaminants into non-contaminated sites as dust or leachate and contribute towards contamination of our ecosystem (Ghosh and Singh, 2005) . A wide range of inorganic and organic compounds cause contamination, these include heavy metals, combustible and putriscible substances, hazardous wastes, explosives and petroleum products. Major component of inorganic contaminants are heavy metals (Adriano,1986 and Alloway,1990). They present a different problem than organic contaminants. Soil microorganisms can degrade organic contaminants, while metals need immobilization or physical removal. Although many metals are essential, all metals are toxic at higher concentrations, because they cause oxidative stress by formation of free radicals. Another reason why metals may be toxic is that they can replace essential metals in pigments or enzymes disrupting their function. Thus metals render the land unsuitable for plant growth and destroy the biodiversity (Ghosh and Singh, 2005).

Soil polluted with HMs pose a health hazard to humans as well as plants and animals, often requiring soil remediation practices (Greman, 2005). Soil Clean up technologies include phsico-chemical methods such as immobilization of metals in soils or their removal through cation exchange with clay minerals, or through complexation with natural or artificial chelating agents (Baker et al., 1994 and Morel et al., 1996). These techniques are very expensive, furthermore; they destroy the soil structure and leave it biologically inactive. Methods currently available are not satisfactory for cleaning up gardens or larger area indended to be used for agriculture (McGrath, 1987). Heavy metal phytoextraction has emerged as a promising, cost-effective alternative to the conventional engineering-based remediation methods (Salt et al., 1995). Phytoextraction research focused on hyperaccumulating plants which have the ability to concentrate high accumulate element (Cunningham, 1995). More than 400 hyperaccumulator species have been identified (Brooks, 2000), most of them associated with metal rich soils. There are currently accumulator species described in the literature for latin America (Ginocchio and Baker, 2004). The application of phytoremediation techniques using hyperaccumulators, has raised some concern related to invasiveness and disruption of indigenous ecosystems (Angle et al., 2001), because the introduction of alien plants may alter ecosystem function, therefore one alternate option is to find native hyperaccumulator plants from polluted regions and use them for soil remediation in the same region, because some plants have adapted to grow on polluted sites, it is possible to find and use them to revegetate on polluted soils either for extraction or stabilization of these elements. The goal of the present study were (1) to investigate polluted soils surrounding in Suez Gulf area to identify endemic excluder, accumulator and hyperaccumulator plant species or ecotypes, and in the medium term to evaluate their capability to remove heavy metals from the soil to which can be use as phytoremediator plants. (2) to investigate the HMs effects on anatomical features of tested plant.

MATERIALS AND METHODS

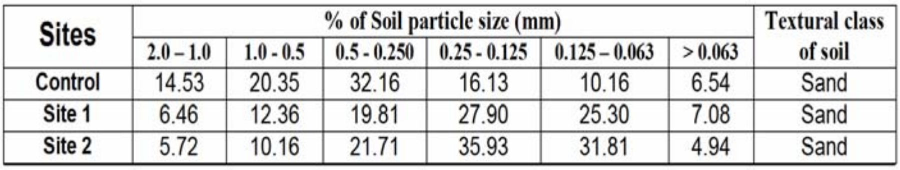
Three sites were selected surrounding oil companies in Suez Gulf, Egypt to carry out the present investigation at N 29^0 $57^{\backslash}$ $15^{\backslash\backslash}$ & E 32^0 $31^{\backslash}$ $39^{\backslash\backslash}$ two sites of them are highly affected with the pollution source (oil companies) where wastes have been spread on soils by natural agencies, i.e; wind, rainfall water …etc (site 1 adjacent the Fence companies & site 2 away 50 m) and the third site was far away from the pollution source and considered as a control site.

Random samples of natural vegetation plant parts of Tamarix *nilotica* and related soil samples of the root zone (0 – 30 cm) were collected and prepared for analysis from the three sites.

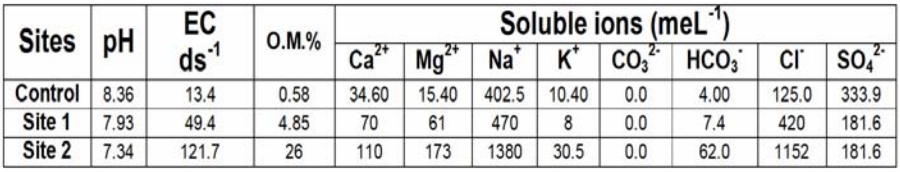
Soil analysis:

Collected soil samples for this study were air-dried, crushed, sieved through 2mm sieve. Soil samples were analyzed pH, total salinity (EC), cationic and anionic compositions according to the methods described by Richards (1954) and Jackson (1963), while total carbonates was determined by the method of Piper (1950). Soil texture of soil samples were accomplished according to Jackson (1967), and represented in table (1).

Table (1): Physicochemical analysis of tested soil (1:1) dilution:



Sites	% of Soil particle size (mm)						Textural class of soil
	2.0 – 1.0	1.0 - 0.5	0.5 - 0.250	0.25 - 0.125	0.125 – 0.063	> 0.063	
Control	14.53	20.35	32.16	16.13	10.16	6.54	Sand
Site 1	6.46	12.36	19.81	27.90	25.30	7.08	Sand
Site 2	5.72	10.16	21.71	35.93	31.81	4.94	Sand



Sites	pH	EC ds^{-1}	O.M.%	Soluble ions (meL^{-1})							
				Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
Control	8.36	13.4	0.58	34.60	15.40	402.5	10.40	0.0	4.00	125.0	333.9
Site 1	7.93	49.4	4.85	70	61	470	8	0.0	7.4	420	181.6
Site 2	7.34	121.7	26	110	173	1380	30.5	0.0	62.0	1152	181.6

The soil samples were analyzed for total content of the studied elements in the filtered extracts obtained from samples digested by conc. HNO_3 + conc. H_2SO_4 + 60% $HCLO_4$ as outlined by Hesse (1971). The chemical-extractable contents of these elements were extracted using DTPA (Diethylene Triamine Pentaacetic Acid), to determine available heavy metals content according to Lindsay and Norvell (1978) and modified by Norvell (1984). In all cases, total and available elements were determined by inductively coupled plasma optical emission spectrometry (ICP).

Plant analysis:

Each of the plant organs sample (root, stem and leaf) was digested according to Norvell (1984). The heavy metals content in plant tissues were determined of diluted digested samples by aspirating directly to (ICP) for each element Al, B, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, V & Zn, the result were obtained using the standard calibration curves.

Anatomical studies of plant:

The tested plant parts i.e., stem and leaf were collected from two polluted sites and the control. Samples of stem were taken from the mature stems, others samples were taken from the mature leaves (Fourth node on the shoot from the terminal end) during the summer time (July- August). Each sample comprised of three mature leaves. The specimens were taken from the leaf between the mid vein and the leaf margin. Samples were fixed in FAA 70%. Dehydration, infiltration and imbedding processes of samples were carried out according to Johansen, (1940). Transverse sections were cut by a rotary microtome with a thickness of 8 – 10 microns. Sections were stained by safranin FCF, malachite green then mounted in Canada balsam. Three sections were examined and photographed by Zeiss microscope at different power.

Statistical analysis:

To estimate the relationship between DTPA-extractable Al, B, Cd, Co, Cu, Fe, Mn, Mo, Ni, V and Zn and some soil variables, correlation coefficients was computed and the obtained correlation equations for the significant relations are presented on Figures using Excel program.

Mean concentration of the metals in plant roots, stems and leaves and soil total and DTPA-Extractable heavy metals were computed and tabulated. Metal ratios as concentrations in stems and leaves relative to roots were made to represent metal distribution in plant using Excel program.

RESULTS AND DISCUSSION

Soil characteristics:

Analytical data (Table 1) show that most of the soil samples are sand-textured, organic matter contents are generally high 26% at site 2 due to petroleum condensed pollution and 4.85% at site 1 compared to 0.58% in control samples. Salinity of the saturation extraction extract, as evidenced by the EC values, is commonly high (EC = 49.4 & 121.7 ds^{-1}) in site 1 & site 2, respectively, compared with 13.4 ds^{-1} in control site. Values of soil pH ranged from 7.93 in site 1 and 7.34 in site 2, indicating that the soils are slightly alkaline and alkaline in control 8.36. The cationic composition of soluble salts are mostly dominated by Na^+ followed by Ca^{2+} and/or Mg^{2+}, then K^+ is the least cation. Soluble anions are mostly dominated by Cl^- followed by SO_4^{2-}, then HCO_3.

Soil metals content:

The Mean of total and DTPA-Extractable heavy metals in surface soil (0 – 30 cm) from highly polluted sites HMs, and control area in Suez Gulf are shown in Table (2). Total heavy metals concentration of polluted soils were increased by 2.23, 2.65, 10.14, 10.67 and 2.691 times in site 1 while 1.66, 2.45, 2.22, 3.44 and 1.10 times in site 2 for Fe, Mn, Ni, V and Zn, respectively compared to the control site.

While total concentration of other heavy metals were increased by 1.05, 1.75, 2.89, 4.18, 3.54 & 2.16 times in site 1 and 1.38, 2..18, 2.52, 2.81, 1.56 & 1.29 times in site 2 for B, Cd, Co, Cr, Cu and Mo, respectively compared to their soil control site.

Following the polluted soil, sites changes widely and considerably with length of waste addition period, these changes varied with the total amount, fraction type, soil depth and nature of element, Data in Table (2) indicate that the concentration of total heavy metals in polluted sites soil is higher than the control one. However, the concentration of these elements in both sites decreased downwards to the DTPA-Extractable. The availability of these elements may be due to the conversion of these elements to the soluble form as a result of the biodegradation of the organic wastes in the sludge which results in organic acids having functional groups that can complex the elements (Gamble et al., 1984).

Table (2): Means of total and DTPA-Extractable metal concentrations (mg/kg) in surface soil (0-30cm) from Suez Gulf area:

Metal	Control		Site 1		Site 2	
	Total	DTPA-Extractable	Total	DTPA-Extractable	Total	DTPA-Extractable
Al	61.45	N.D.	5425	0.1308	4562	2.27
B	19.44	1.602	26.81	2.391	35.168	6.388
Cd	0.01	N.D.	0.175	0.013	0.218	0.044
Co	1.53	0.155	4.49	0.038	3.91	0.36
Cr	N.D.	N.D.	33.06	0.068	22.27	0.169
Cu	5.90	0.44	20.93	1.07	9.18	2.19
Fe	3062	11.45	6842.5	20.6	5077.3	41.15
Mn	42.02	6.886	111.13	2.23	102.93	18.18
Mo	0.95	N.D.	2.05	0.15	1.23	0.197
Ni	12.30	0.234	124.8	0.34	27.36	1.049
V	18.80	0.813	192.05	2.88	61.9	1.82
Zn	49.50	2.418	67.28	3.54	27.58	17.44

To substantiate the relationship between DTPA-extractable Al, B, Cd, Co, Cu, Fe, Mn, Mo, Ni, V and Zn and some soil variables, correlation coefficients was computed. The obtained coefficients indicate that DTPA-extractable Cd & Cu & Fe are significant positively correlated with EC_e (r^2=0.998, 0.999 and 0.999; respectively). Extractable B and Ni are also significant positively correlated with O.M. % by (r^2=1 and 0.998, respectively). While extractable Cr and Cu being significant negatively correlated with pH (r^2= 0.999 and 0.995; respectively). Other relations of metals extractable with chemical characteristics are non-significant. The obtained correlation equations for the significant relations are presented on Figure (1).

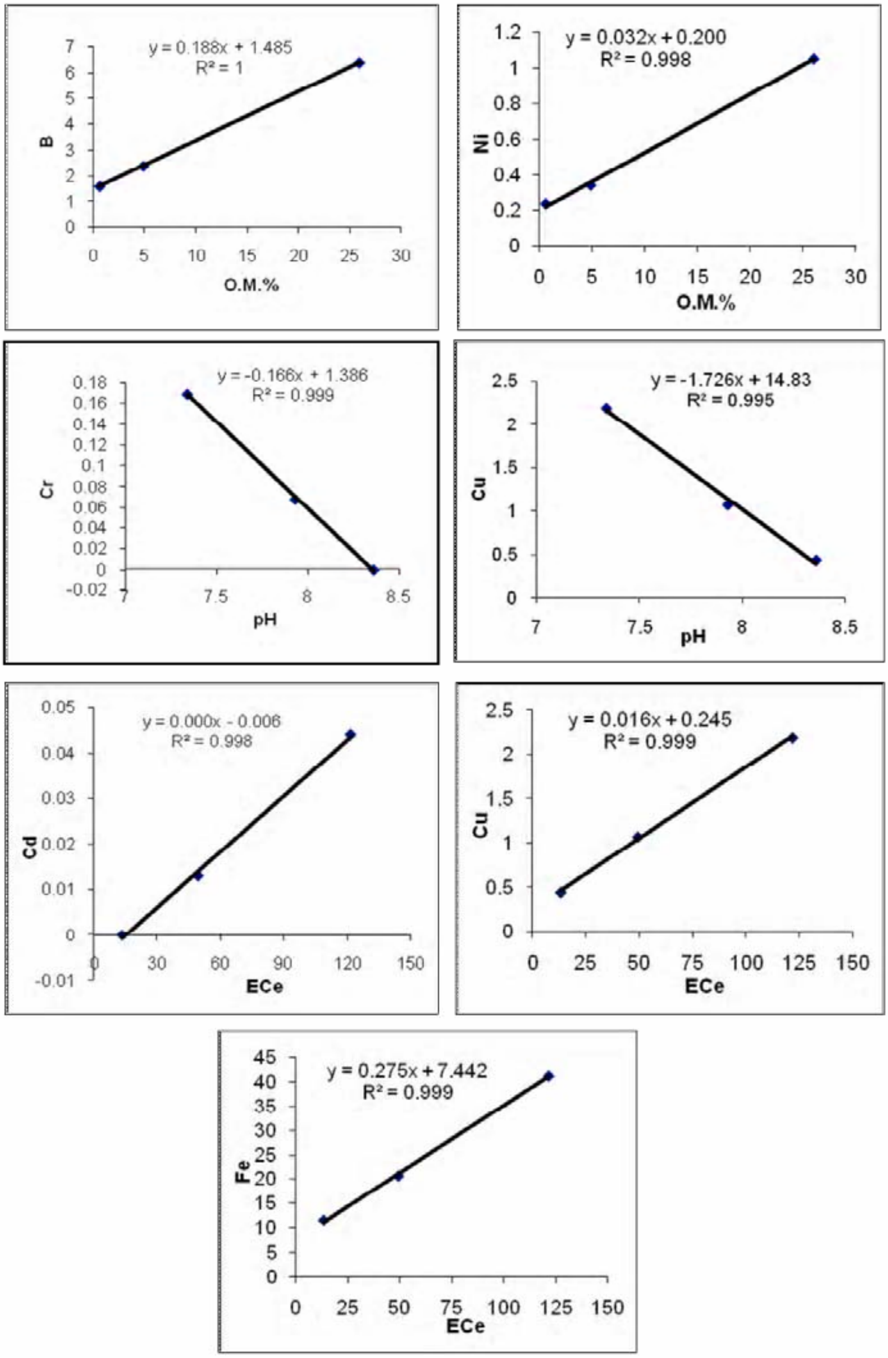


Figure (1): Correlation between soil available metals and soil variables.

Plant metals content:

Mean concentration of the metals in the roots, stems and leaves of *Tamarix nilotica* grown on the polluted and control soils are shown in Table (3), despite the high variability, They were comparable to values reported by Ali et al., (2001) for *Tamarix nilotica* from wadi Allaqi on the shore of lake Nasser in the Eastern Desert of upper Egypt.

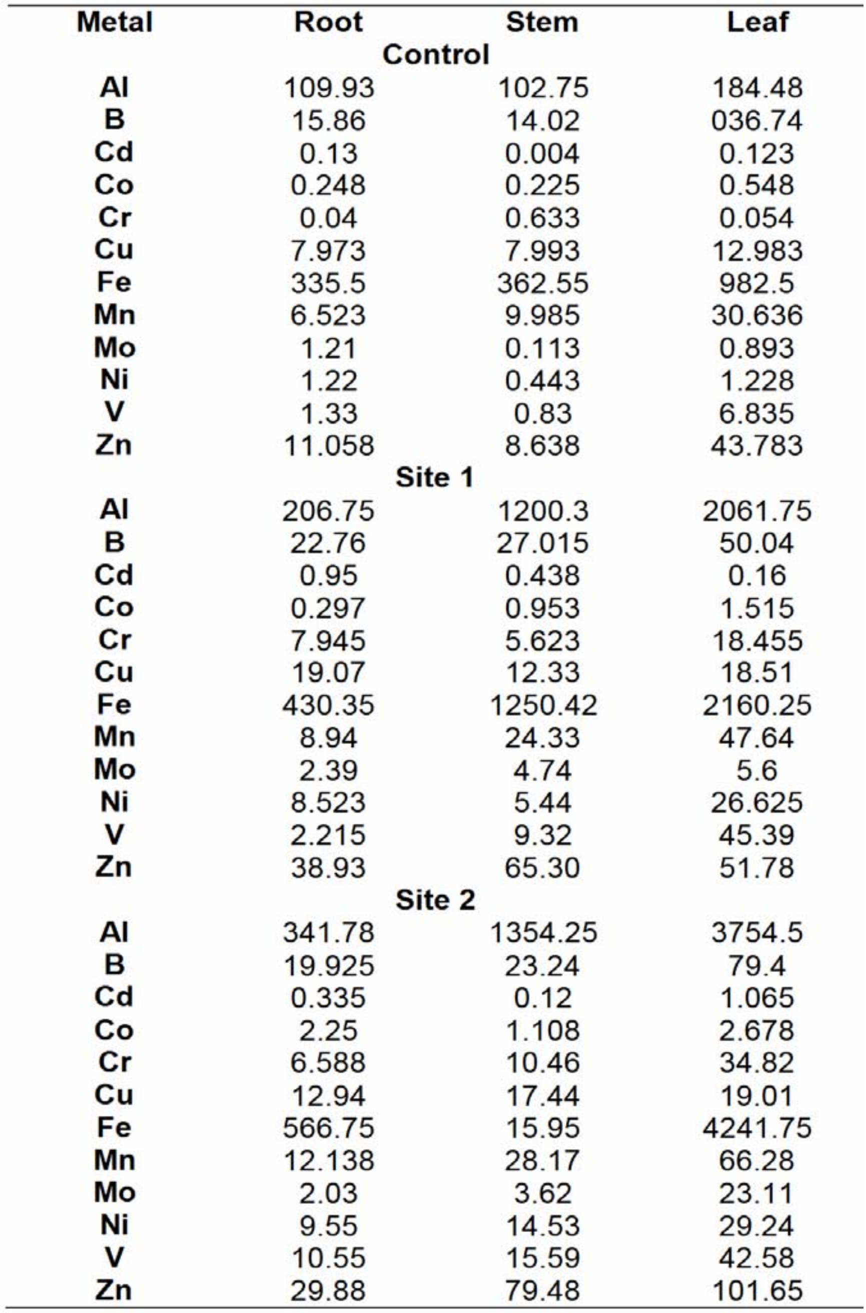
The mean concentrations Al, B, Cr, Cu, Fe, Mo & V in leaf tissue were all above the range commonly quoted for plant tissue concentrations. (Mengel and Kirby, 1978), while the value for Co, Mo, Ni and Zn were within this range. In all cases except Co, Cu, Mn, Ni and Zn the mean concentrations in leaf tissue were all above the normal range; Cu was at the top end of the range.

Data in Table (4) represented the metal distribution in *Tamarix nilotica* as concentrations ratios in stems and leaves relative to roots. The data revealed that all elements were concentrated in the leaves relative to the stems and the roots which indicate that *Tamarix nilotica* absorb and translocate metals from soil to stem and leaves.

Plant can accumulate heavy metals essential for growth and development such as Fe, Mn, Zn, Cu, Mg, Mo, and possibly Ni. In addition some of them have the capacity to accumulate heavy metals with unknown biological functions, such as Cd, Cr, Pb, Co, Ag, Se and Hg (Baker and Brooks, 1989 and Raskin et.al., 1994). For the metabolism of metals, plants require a balance between the uptake of essential metal ions to maintain growth and development and have the ability to protect sensitive cellular activity and structures from excessive levels of essential and non-essential metals

However, naturally occurring plants in polluted areas called metal hyperaccumulators can accumulate 10 – 500 times higher levels of elements than crops (Chaney et al., 1997). Unfortunately, most hyperaccumulators are relatively small in size, have slow growth rate. Therefore, a lot of research emphasis has been placed on the evaluation of metal-accumulating capacity of high biomass plants that can be easily cultivated using established agronomic practices (Salt et al., 1995; Raskin et al., 1997).

Table (3): Mean of metal concentration (mg/kg) in root, stem and leaf of *Tamarix nilotica*:



Metal	Root	Stem	Leaf
		Control	
Al	109.93	102.75	184.48
B	15.86	14.02	036.74
Cd	0.13	0.004	0.123
Co	0.248	0.225	0.548
Cr	0.04	0.633	0.054
Cu	7.973	7.993	12.983
Fe	335.5	362.55	982.5
Mn	6.523	9.985	30.636
Mo	1.21	0.113	0.893
Ni	1.22	0.443	1.228
V	1.33	0.83	6.835
Zn	11.058	8.638	43.783
		Site 1	
Al	206.75	1200.3	2061.75
B	22.76	27.015	50.04
Cd	0.95	0.438	0.16
Co	0.297	0.953	1.515
Cr	7.945	5.623	18.455
Cu	19.07	12.33	18.51
Fe	430.35	1250.42	2160.25
Mn	8.94	24.33	47.64
Mo	2.39	4.74	5.6
Ni	8.523	5.44	26.625
V	2.215	9.32	45.39
Zn	38.93	65.30	51.78
		Site 2	
Al	341.78	1354.25	3754.5
B	19.925	23.24	79.4
Cd	0.335	0.12	1.065
Co	2.25	1.108	2.678
Cr	6.588	10.46	34.82
Cu	12.94	17.44	19.01
Fe	566.75	15.95	4241.75
Mn	12.138	28.17	66.28
Mo	2.03	3.62	23.11
Ni	9.55	14.53	29.24
V	10.55	15.59	42.58
Zn	29.88	79.48	101.65

Table (4): Metal distribution in *Tamarix nilotica* as concentrations ratios in stems and leaves relative to roots.

Metal	Control	Site 1	Site 2
	Root : Stem : Leaves ratios		
Al	1 : 0.93 : 1.35	1 : 5.81 : 9.97	1: 3.96 : 10.98
B	1 : 0.88 : 2.32	1 : 1.19 : 2.19	1 : 1.17 : 3.98
Cd	1 : 0.03 : 1.94	1 : 0.46 : 0.17	1 : 0.36 : 3.18
Co	1 : 0.91 : 2.21	1 : 3.20 : 5.09	1 : 0.49 : 1.19
Cr	1 :15.81 : 1.35	1 : 0.71 : 2.32	1 : 0.59 : 5.29
Cu	1 : 1.00 : 1.63	1 :0.65 : 0.97	1 : 1.35 : 1.47
Fe	1 : 1.08 : 2.93	1 : 2.91 : 5.02	1 : 2.81 : 7.48
Mn	1 : 0.53 : 4.69	1 : 2.72 : 5.33	1 : 2.32 : 5.46
Mo	1 : 0.93 : 0.74	1 : 1.94 : 2.34	1: 1.78 : 11.39
Ni	1 : 0.36 : 1.01	1 : 0.64 : 3.12	1 : 0.52 : 3.06
V	1 : 0.62 : 5.14	1: 4.21 : 20.49	1 : 1.48 : 4.04
Zn	1 : 0.78 : 3.96	1 : 1.68 : 1.33	1 : 2..66 : 3.40

Effect of heavy metals pollution on Anatomical features:

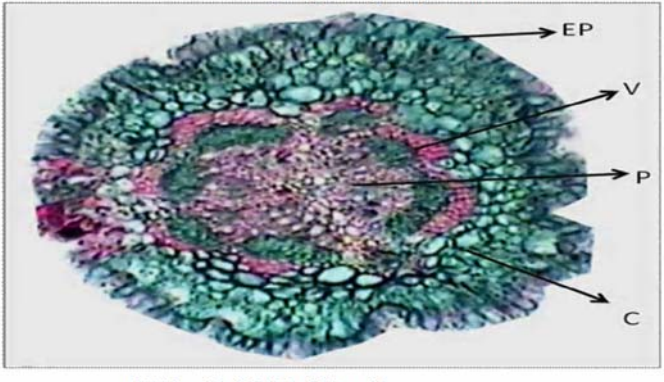
The anatomical features of *Tamarix nilotica stem & leaves grown on the* two polluted sites were compared with same plant parts grown under controlled conditions.

Stem anatomical observations:

Structure in Figure (2) illustrates cross sections of *Tamarix nilotica* stem inhibit the studied sites. The Figure shows stem of the control site to consist of the ordinary tissues the epidermal, the vascular and the cortical tissues (control). Sections of plants from site 1 showed the secondary growth and the amounts of secondary tissues were more obvious and the outer tangential walls of the epidermal cells are thicker than those of the control plants. While these of site 2 showed the vascular and the ground tissues differentiate into a narrow cortex and pith.

[Fig.2 (A)] Control

[Fig.2 (B)] Site 1



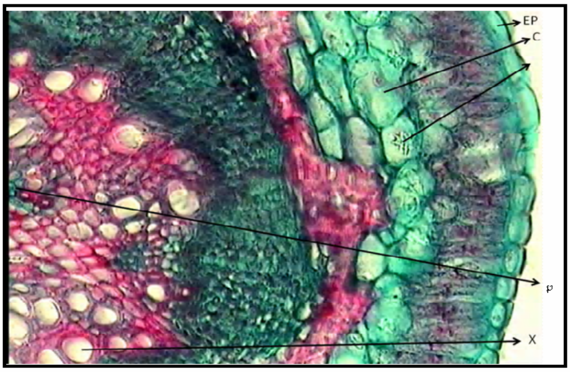
[Fig.2 (C)] Site 2

Fig. (2): T. S. in the stem showing heavy metals pollution effect of different sites of *Tamarix nilotica* plant X.80.

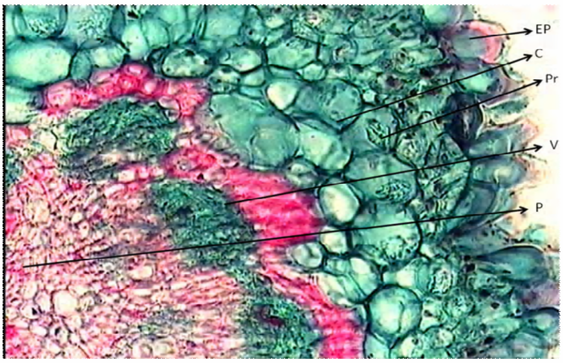
EP: Epidermis C : Cortex

V : Vascular bundle P : Pith

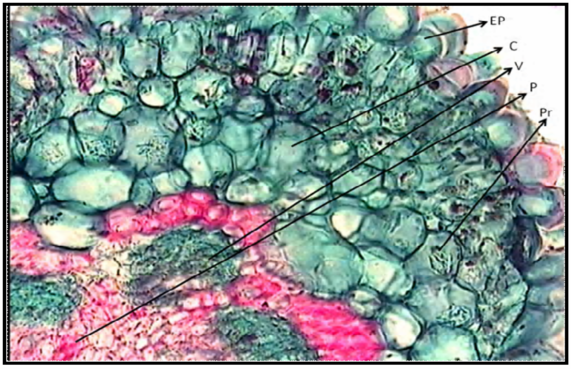
Figure (3) showed that for the control site stem, the ground tissue differentiates into a narrow cortex and pith. The epidermis is uniseriate i.e., consists of a single layer of cell having few stomata and simple hairs.



[Fig.3 (A)] Control



[Fig.3 (B)] Site 1



[Fig.3 (C)] Site 2

Fig. (3): T. S. in the stem showing heavy metals pollution effect of different sites of *Tamarix nilotica* plant X180.

EP: Epidermis C : Cortex V : Vascular bundle
P : Pith Pr :prismatic crystals

The cortex consists of parenchymatous cell layers. the outermost cells of the first cortical layer lack chloroplasts. The inner cortical cells are chloroplast free, the endodermis cells contain solitary prismatic crystals.

It is noticeable for the stem section of site 1 that most of the cortical cells have chloroplasts. Four strands of collenchyma were differentiated beneath the epidermis. This collenchyma was weakly developed in the control plants. The solitary crystals in the endodermis cells were fewer in numbers compared with the control plants.

Stem section of site 2 shows the uniseriate epidermis have a lots of stomata in contrast for those few ones of the control plants. The cells of the first cortical layer lack chloroplasts. The inner cortical cells are chloroplast free, the cells of the innermost layer i.e., the endodermis contain solitary prismatic crystals. Most of the cells of the pith are completely destroyed.

Leaf anatomical observations:

Accurate examination of leaf cross sections illustrated in Figure (4) shows that – with concern of control site *Tamarix nilotica* leaf has epidermal layers, mesophyll tissue and the vascular bundles. The lower epidermal cells have regular size and shape and are arranged in the same level. The upper epidermis, constitutes alternate wide ridges. The vascular bundles of the leaf occur in the aforementioned ridges, one bundle in each ridge. Both the upper and lower epidermal cells opposite the vascular bundles have smaller size and thicker walls than the other epidermal cells.

The mesophyll consists of homogenous chlorenchymatous cells. The midvein region has three vascular bundles; the middle is larger than the laterals. The vascular bundle has xylem toward the upper epidermis and phloem towards the lower one. The xylem consists of two large vessels near the phloem and some trachieds between them as well as one or two small protoxylem vessels toward the upper side. In the large bundles one of the protoxylem vessels becomes destroyed leaving a small cavity, i.e., the protoxylem lacuna. The phloem consists of small sieve elements and smaller companion cells. The vascular bundle is surrounded by two sheaths; the inner one is sclerenchymatous while the outer is parenchymatous with conspicuous chloroplasts. The outer sheath extends to connect with the lower epidermis and the upper epidermis. These bundle sheath extensions have large parenchyma lacking chloroplasts except near the epidermal cells where their cells become smaller and have thickened lignified walls. A narrow zone of large parenchymatous cells occupies the central part of the midvein.

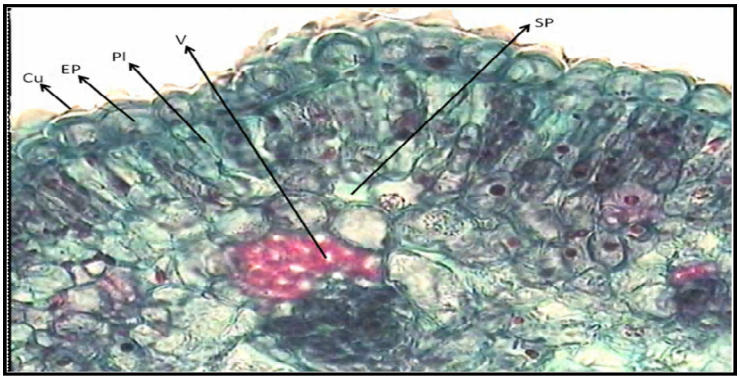
Anatomical changes of the site1 sections are obvious with the ridges, the vascular bundles are smaller than those of the control plants.

With respect to site 2 plants, the structure of the leaf is similar to that of control. The ridges are smaller than those of the control plant leaf. The ridges may also extend toward the lower surface. The lower epidermal cells facing the lower furrows are larger the other epidermal cells.

Resistance of plant to heavy metals ions can be achieved by an avoidance mechanism, which includes mainly the immobilization of metal in root and in cell walls. Tolerance to heavy metals is based on the sequestration of heavy metal ions in vacuoles, on binding them by appropriate ligands like organic acids, proteins and peptides and on the presence of enzymes that can function at high levels of metallic ions. (Harbone, 1989; Robinson et. al., 1994).

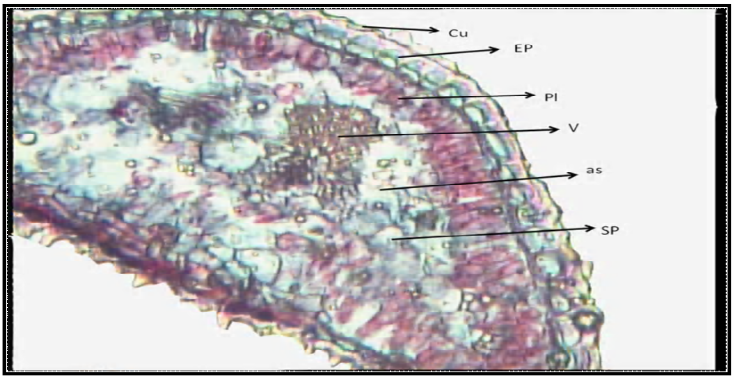
Maruthi Sridhar et al., (2004) investigated the anatomical changes due to uptake and accumulation of Zn and Cd in Indian mustard (*Brassica juncea*). They noticed clotted depositions in roots and stems, break down of parenchyma cells, and a decrease in starch content in leaves of plants treated with high concentrations of Zn.

Cheng et al., (2010) studied the role of radial oxygen loss and root anatomy on zinc uptake and tolerance in mangrove seedlings. The results revealed that *Bruguiera gymnorrhiza* , which possessed the ‘tightest barrier’ in ROL spatial patterns among the three species studied, took up the least Zn and showed the highest Zn tolerance. Furthermore, zinc significantly decreased the radial oxygen loss (ROL) of all three plants by inhibition of root permeability, which included an obvious thickening of outer cortex and significant increases of lignification in cell walls.



[Fig.4 (A)] Control X. 250

[Fig.4 (B)] Site 1 X. 250



[Fig.4 (C)] Site 2 X.180

Fig. (4): T. S. in the leaf showing heavy metals pollution effect of different sites of *Tamarix nilotica* plant

Cu: Cuticle EP. : Epidermis Pl.: Palisade V.: vascular bundle as. : Air spaces SP.: Spongy X. : Xylem.

Conclusion:

In present study, we found that either high positive or negative correlation of some soil variables with available heavy metals. These soil variables could be used as indicators for the level of pollution. Also, significant structural changes in stems and leaves of *Tamarix nilotica* were observed due to the high availability of heavy metals in soil.

Tamarix nilotica plants can accumulate significant amounts of heavy metals without showing phytotoxicity or reduction in plant growth & development.

The ideal plant to be used in phytoextraction should have the following characteristics: 1) be tolerant to high levels of the metals. 2) accumulate high levels of the metal in its harvestable parts. 3) have a rapid growth rate; 4) have the potential to produce root system.

Thus *Tamarix nilotica* plant has high bioaccumulation factors for metals, high biomass and has a profuse root system, thus *Tamarix nilotica* can acts as an ideal plant to be used in phytoextraction processes in heavy metal polluted areas.

REFERENCES

Adriano, D. C. (1986). Trace elements in the terrestrial environment.- Springer- Verlage, New York, pp, 533.

Ali, M. ; Badri, M. A. ; Moalla, S. N. and Pulford, I. D. (2001). Cycling of metals in desert soils: Effects of *Tamarix nilotica nilotica* and inundation by lake water. Environmental Geochemistry and Health. 23: 373 – 382.

Allowy, B.J. (1990). In Heavy metals in soils (ed Alloway B.J.),Blackie, Glasgow.

Angle, J.; Chaney, R.; Li, Y. M. and Baker, A. (2001). The risk associated with the introduction of native and hyperaccumulators plants. Abstract. USDA, Agricultural Research Service, USA.

Baker, A. J. M. and Brooks, R. R. (1989). Terresterial higher plants which hyperaccumulate metallic elements. A review of their distribution, ecology and phytochemistry. Biorecovery. 1, 81-126.

Baker, A. J. M.; Mc Grath, S.P.; Sidoli C.M.D. and Reeves, R.D.(1994). The possibility of in situ heavy metal decontamination of polluted soils using crops of metal accumulating plants. Resource Con-ser Recycling. 11:41-49.

Brooks, R. R. (2000). Plants that hyperaccumulate heavy metals. CAB International, Cambridge, UK, pp. 380.

Chaney, R. L.; Malik, M. M; Li, Y.M.; Brown, S.L.; Brewer, E. P.; Angle, J. S. and Baker, A. J. M. (1997). Phytoremediation of soil metals. Current Opin. Biotechnol. 8, 279 – 284.

Cheng, H; Liu, Y.; Tam, N.F.Y.; Wang X.; Li d, S.Y.; Chen, G.Z. and Ye, Z.H. (2010). The role of radial oxygen loss and root anatomy on zinc uptake and tolerance in mangrove seedlings. Environ. Pollut., doi:10.1016/j.envpol.2010.01.025

Cunningham, S.C.; Berti, W.R. and Huang, J.W.(1995). Remediation of contaminated soils and sludges by green plants.V : Bioremediation of inorganics. Hinchee E., Means J.L., and Burris D. (eds). Columbus-Richland,Batelle Press: 33-54.

Gamble, D. S.; Landford, C. H. and Underdown, A. W. (1984). In "The interrelationship of aggregation and cation binding of fulvic acid: Complexation of trace metals in natural waters" p. 349-356. (Kramer, C.J.H. and Duinker, T. C. eds.). Martuns Xlighoff. Junk Publishers. The Hafue Netherlands.

Ghosh, M. and Singh, S. P. (2005). A Review of phytoremediation of heavy metals and utilization of its byproducts. Applied Ecology and Environmental Research. 3,1:1-18.

Ginocchio, R. and Baker, A.J.M. (2004). Metallophytes in Latin America: a remarkable biology and genetic resource scarcely known and studied in the region. Rev. Chill. Hist. Nat. 77, 185-194.

Greman, H. (2005). Phytoextraction of heavy metals from contaminated soil: expectations and limitation. Geophysical Research Abstracts, Vol. 7: 001117.

Harbone, R.D. (1983). Effect of soil pH on adsorption of lead, copper, zinc and nickel. Soil Sci. Am. J. 47, 47-51

Henry J.R. (2000). In An overview of phytoremediation of lead and mecury.-NNEMS Report. Wasnington, D.C.;pp,3-9.

Hesse, P.R.(1971). A textbook in soil chemical analysis. William Glowe, London.

Jackson, M. L.(1963). Soil chemical analysis. Constable and Comp. Ltd., England.

Jackson, M. L. (1967). Soil chemical Ananlysis. India: prentice Hall, Inc. Engl. Wood Cliffs, New Jersy.

Johansen, D. A. (1940). Plant microtechnique. MC Graw-Hill Book Company, New York pp. 523

Jones, J. B. (1991). Plant tissue analysis in micronutrients, in : JJ. Mortvedt et al., (eds). Micronutrients in agriculture soil science of America, Madison, pp. 477 – 521.

Lindsay, w. L. and Norvell, W. A. (1978). Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Am.J.42, 421-428.

Maruthi Sridhar, B.B.; Diehl, S.V.; Han, F.X; Monts, D.L. and Sub,Y.(2004). Anatomical changes due to uptake and accumulation of Zn and Cd in Indian mustard (*Brassica juncea*). Environmental and Experimental Botany 54 (2005) 131–141

McGrath, S.P. (1987). Long-term studied of metal transfers following applications of sewage sludge. In pollutant transport and fate in Ecosystems Eds, PJ. Coughtery, M. H. Martin and Unsworth, pp. 301 – 317. Special publication No. 6. Of the British Ecological society. Blackwell scientific. Oxford.

Mengel, K. and Kirby, E. A. ; (1978). Principles of plant Nutrition, Berne, International Potash Institute, 593 pp.

Morel, J.L.; Bitton, G.; Schwartz, C. and Schiavon,M.(1996). In Ecotoxicology. Responses, Biomarkers and Risk Assessment, Zelikoff, J.T.,Ed.,OECD workshop; SOS publications, Fair Haven,N.J.37-74.

Norvell, W.A.(1984). Comparison of chelating agents as extractants for metals in diverse soil materials. Soil Sci. Soc. Am. J., 48, 1285 –1292.

Ohanson, D.A. (1940). Plant microtechnique Mc Graw-Hill Book company, New York pp. 523.

Piper, C. S. (1950). Soil and plant analysis. A monograph from the Waite Agric.Res.Inst. Adelaide Univ.,S.A.,Australia.

Pulford, I.D., Murphy, K.J., Dickinson, G., Briggs, J.A. & Springuel, I. (1992). Ecological resources for conservation and development in Wadi Allaqi, Egypt. Botanical Journal of the Linnaean Society, 108: 131}141.

Raskin, I.; Kumar, P.B. A. N.; Dushenkov, S. and Salt, D. E. (1994). Ioconcentration of heavy metals by plants. Curr. Opin. Biotechnol. 5, 285 – 290.

Raskin, I.; Smith, R. D. and Salt, D. E. (1997). Phytoremediation of metals: using plants to remove pollutants from the environment. Curr. Opin. Biotechnol. 8, 221 – 226.

Richards, L. A. (1954). Diagnosis and improvement of saline and alkali soils. U.S. Dep. Agric. Handbook. No. 60.

Robinson, N. J.; Urwin, P.E.; Robinson, P.J. and Jackson, P.J. (1994). Gene expression in relation to metal toxicity and tolerance. In: Basra, A. S. (Ed.), Stress-Induced Gene Expression in plants. Harwood Academic Publish, New York, pp.209-248.

Salt D.E., Blaylock, M. ; Kumar, P. B. A.N.; Dusenkov, V.; Ensely, B.D.; Chet, I, and Raskin, I.(1995). Phytoremediation: a novel strategy for the removal of toxic metals from the environment using plants. Biotechnology, 13: 468 – 474.

Wind, A. (1988). Russell's soil conditions and plant growth, 11 th edn, Longman Scientific and Technical, Harlow, 991 pp.

التغيرات التشريحية الناتجة عن إمتصاص و تراكم العناصر فى نبات التامركس المحب للمعادن

رهام كامل إبراهيم بدوى و إيمان على دياب

وحدة تلوث البيئة – قسم البيئة النباتية و المراعى – مركز بحوث الصحراء – المطرية – القاهرة - مصر

فى هذه الدراسة تم التقييم الكمي لمستويات التلوث والتغيرات التشريحية لنبات الأثل النامى في منطقة خليج السويس بمصر ، حيث يتم معالجة واستخراج النفط ويتركز تلوث التربة للمناطق المحيطة بها والتى يتم انتشار النفايات دون أي نظام لحماية البيئة من التلوث. تم قياس تركيزات العناصر الثقيلة : الألومنيوم – البورون - الكادميوم – الكوبالت - الكروم - النحاس - الحديد – المولبيدنيوم – النيكل – الفانيديوم والزنك في التربة وأجزاء نبات الأثل: الجذور ، السيقان والأوراق.

تم حساب معامل الارتباط بين مستخلص التربة DTPA من الكادميوم - النحاس والحديد ارتباطاً طرديا مع تركيز الأملاح ($r^2 = 0.998, 0.999 \& 0.999$ على التوالي) ، ومستخلص البورون والنيكل ارتيط ارتباطا إيجابيا مع نسبة المادة العضوية بقيم ارتباط ($r^2=1 \& 0.998$ على التوالي). بينما الكروم والنحاس يتناسب عكسيا مع درجة الحموضة ($r^2 = 0.999 \& 0.995$ على التوالي).

وتركزت جميع العناصر في أوراق النباتات بالنسبة الى السيقان والجذور. ، كما احتوت جميع أجزاء النبات على مستويات عالية من العناصر الثقيلة مقارنة مع محتواها فى نباتات المقارنة.

وقد تم ملاحظة تغيرات تشريحية فى المقاطع العرضية للساق و الورقة نتيجة لامتصاص النباتات للمعادن الثقيلة. ومن الجدير بالذكر أن نتائج هذا البحث تقدم دليلا قويا على إمكانية إستخدام نبات الأثل كنات مثالي في عمليات الاستخلاص الحيوى phytoextraction للأراضى الملوثة في المستقبل .