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Fagonia boveana as a biomonitor for exploration and remediation of some trace elements from soil in Qattar area, North Eastern Desert, Egypt

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ABSTRACT

Plants in Gebel Qattar are condensed in the course of rainwater that is coming from top of mountain. In the present study, the plant samples are collected from four studied sectors: Qattar I (QI), Qattar II (QII), Qattar V (QV) and Wadi El Abde.

From the distribution of the As, Bi, V, Ga, Cr, and Sn in the studied soil samples, it was found that QI, QII and Wadi El Abde sites contain the highest concentration of As, Bi, V, Ga, Cr, and Sn. relative to QV. Among the plant samples, it was found, *Fagonia boveana* has the ability to absorb and concentrate As, Bi, V, Ga, Cr, and Sn. Therefore, this plant is significant for exploration of these elements and can be used for phytoremediation of these elements.

INTRODUCTION

Gebel Qattar area, being a part of the Eastern Desert of Egypt, has a desertic type of climate. It is arid and hot in summer, mild to cold in winter. Temperature is high and ranges between 15°C-20.3°C in winter and 26°C-46°C in summer. The rainfall is occasional and scarce. The main bulk of rain occurs in winter. That coming from top of the mountain towards valley floors. Wind is occasionally strong during the winter season.

G. Qattar area (the study area) is located in the North Eastern Desert, north west of Hurgada city. It is bounded between Longitudes 33o 14' 11'' and 33^0 20' 16'' E and Latitudes 27° 04' 00'' and 27° 08' 30'' N (Figure 1). The floor of the Wadis and their tributaries of Gebel Qattar area are generally covered by thick recent Wadi sediments. These sediments are unconsolidated, loose and consist of fluvial sediments formed of sands, pebbles, gravels, cobbles and boulders. Fluvial soils exist largely because of soil creep in area of high relief.

Phytoremediation is one of the most effective methods of remediation for contaminated soils. This is approved by the United States Environmental Protection Agency. This tool depends on cultivating special plants for uptake and concentration of the poisonous elements and therefore cleans up the soil from contamination.

Plants can accumulate trace elements, especially heavy metals, in or on their tissues due to their great ability to adapt to variable chemical properties of the environment: thus, plants are intermediate reservoirs through which trace elements from soils and move to man and animals. Tiffin[12] has concluded, that the plants may be passive receptors of trace elements (fallout interception or root adsorption), but they also exert control over uptake or rejection of some elements by appropriate physiological reactions. Three general uptake characteristics can be distinguished in plants: accumu-

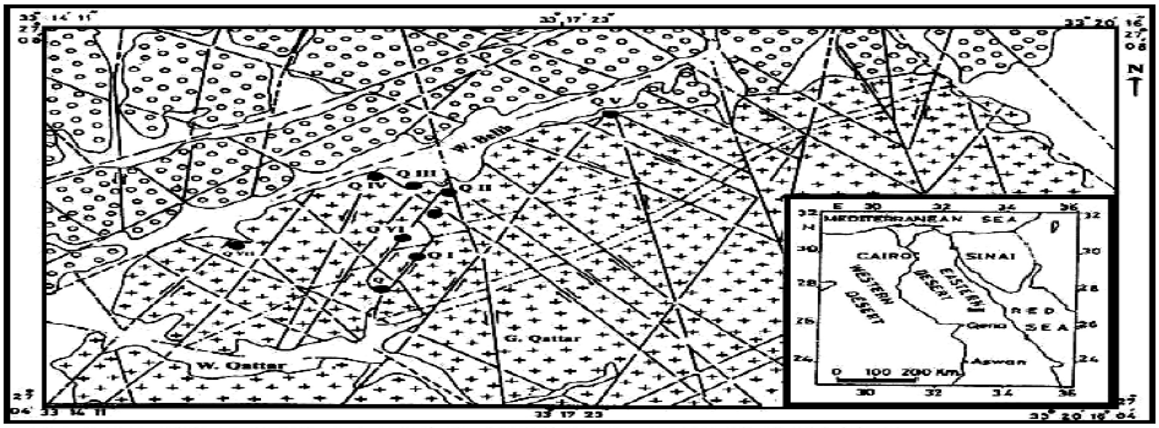

Fig.(1): Geological and structural map of G. Qattar area after Shalaby (1996)
The smaller map shows the location of the study area

0 1 2 Km

Legend

Hammamat Sediments
Pink Granites.
Q I Radioactive Occurrence.
Faults, arrows show relative movemet

lation, indication, and exclusion. To a large extent, this depends on the specific ability of plants. A huge difference in elements uptake between plant species, and also between genotypes of a species, has been demonstrated in many studies. Brooks[17], Prasad[16] and Prasad and Hagemeyer[15].

The current database of the U.S. Environmental Protection Agency contains nearly 25,000 records on 21 metals in plants as related to the uptake, accumulation, and translocation by vascular plants. The highest numbers of records, over 1000, are for the *Zea, Phaseolus*, and *Triticum* families. Nellesser[11]

A high relative proportion of all elements records is Cu 18.6 %, Zn 17 %, Cd 14.4 %, and Pb 9 %. Below 1% records for V, Cs, Th, Sb, Pt, Be, Sn, and U, Alina Kabata (2001). The conclusions of that review indicate that Cd and Hg are considered among the more toxic metals. The most frequently identified elements causing biological/ecological harmful effects are: Pb, Cs, As, Cr, Zn, Ni, and Cu.

This paper deals with the uptake and accumulation of some trace elements from soil such as: As, Bi, V, Ga, Cr, and Sn by using the wild vegetation (*Fagonia boveana)* as indicator for exploration and phytoremediation for these elements.

MATERIAL AND METHODS

Four soil samples and five plant samples were collected from Gebel Qattar area in north Eastern Desert of Egypt. The study area is divided into four sectors, three of these are with more radioactivity which are Qattar (Q) I, II and V. while the fourth sector is barren of radioactivity. This is called wadi El Abde and is taken for comparative purposes with other sectors. Plant and soil samples are collected for determining the concentration and accumulation of some trace elements such as: As, Bi, V, Ga, Cr, and Sn these around to 6 trace elements. All of the chemical analyses for plant and soil samples were carried out at the ACME analytical laboratories, Canada.

Plant samples

Plant samples were collected at blooming duration and put in paper bags until reaching to the lab. The plant samples were carefully cleaned (one by one) with tap water to remove the visible soil and dust and then washed with sterile distilled water several times. The plant samples were classified in herbarium specimens, Botany Department, Faculty of Science, Cairo University.

Plant analysis

Plant samples were dried at 105ºC for 24 h to remove water. The dried samples were crushed and powdered by using Teflon coated stainless steel blender. They are then ashed at 550ºC for 3 hrs in dry oven to remove the organic matter. One gram from each plant ash sample is digested by using 20 ml HNO3 acid for one hour, then 6 ml mixed from 2:2:2 HCL- HNO3- H2O2 at 95ºC for one hour, then the content was diluted to 50 ml by bi-distilled water. Some trace elements such as As, Bi, V, Ga, Cr, and Sn were determined by inductively coupled plasma mass spectrometry (ICP- MS).

Soil samples

Soil samples were collected as a composite of the depth till 30 cm of the soil. In most cases, separate soil samples are collected with associated plant species. The soil samples were put into bags until reaching the lab. and then they are quartered. The representative soil samples were crushed and powdered with the aid of a mechanical agate mortar to 100 mesh size.

Soil analysis

A portion of 0.5 g of the finely powdered soil sample was accurately weighed into Teflon beaker with cover. A mixture of 40 ml HF and 10 ml conc. HCl was added. The covered beaker was heated to 130–140°C, till the acid was evaporated. Then 1:1 HCl was added and the solution was diluted to 100 ml with bi-distilled water.

VEGETATION

Fagonia boveana

Fagonia tristis sickenb. var. *boveana* (Hadidi), was firstly described by El Hadidi[13] and later as *Fagonia boveana*, El Hadidi et al.[14]. Diffusely branched (Figure 2.a), basally suffrutescent, annual or perennial herbs up to 30 – 80cm (Figure 2.b). Leaves opposite, simple or palmately. deciduous or persistent foliolate; stipules often spiny and acicular ; leaflets entire, mucronate. Inflorescence of solitary axillary flowers. Flowers pedicellate, actinomorphic hypogynous, pentamerous, rosy, purplish-pink or violet rarely yellow, hispid patent or ascending. Leaves short petioled. Sepals becoming in fruit and persistent on mature capsules, Tackholm[19], Figure 2.

A ruler is put to measure the natural diversions of the plant. This plant measures, 40x40cm

Figure 2 : *Fagonia boveana*

RESULTS AND DISCUSSIONS

Distribution of As, Bi, V, Ga, Cr, and Sn in soil samples

The collected soil samples are products of mechanical weathering of the granites that covering G. Qattat. These products are transformed into soils by processes of chemical weathering. The soil is fine grained suitable for growing plants, which are the main target in the present study. Soil samples were collected from the four localities and prepared for the determination As, Bi, V, Ga, Cr, and Sn.

Arsenic (As)

The results of arsenic concentration in soils show a narrow range nearly from 1.2 to 1.8 ppm. The concentration of As is 1.3 ppm in Qattar I, 1.4 ppm in Qattar II and 1.2 ppm in Qattar V. While the highest value (1.8 ppm) is recorded in Wadi El Abde location (TABLE 1). According to Alina Kabata[1], arsenic is distributed rather uniformly in major types of rocks and its common concentrations in most rocks range from 0.5 to 2.5 ppm. Only in argillaceous sediments As is on the average concentrated as high as 13 ppm. The same authors refer to the lowest As levels that are found in sandy soils and in particular in those derived from gran-

TABLE 1 : Concentration of As, Bi, V, Ga, Cr, and Sn (ppm) in soils of studied area

Location Element	Qattar I	Qattar II	Qattar V	Wadi El Abde
As	1.3	1.4	1.2	1.8
Bi	0.1	0.3	0.1	0.2
V	5.0	< 5.0	5.0	44.0
Ga	29.6	21.1	24.7	23.3
Cr	44	40	44	124
Sn	7.0	6.0	4.0	6.0

ites, whereas higher As concentrations are mostly related to alluvial soils and soils rich in organic matter. All values of As in the present study are in agreement with Alina Kabata[1].

Bismuth (Bi)

Bismuth distribution in the soils of the studied locations shows some variations. The value of Bi in QI and QV is 0.1 ppm, while in Q II, this value is 0.3 ppm and in Wadi El Abde it is 0.2 ppm (TABLE 1). According to Alina Kabata[1] Bi is considered a rare metal in the earth's crust (around 0.2 ppm) and is usually found in veins associated with some metals such as Ag, Co, Pb and Zn. Its higher concentrations in argillaceous sediments do not exceed 0.5 ppm. Bi element during weathering is readily oxidized, and when it becomes carbonated ($Bi_2O_2CO_3$) it becomes very stable. Therefore, the Bi content of most surface soils is directly inherited from parent rocks. The value of Bi in Wadi El Abde is typically in agreement with Alina Kabata[1].

Vanadium (V)

In the studied locations the vanadium concentration in soil samples is equal to 5.0 ppm in the three locations QI, QII and QV, while its concentration in Wadi El Abde shows a higher value equals 44.0 ppm (TABLE 1). The average V content of soils worldwide have been calculated to vary from 18 ppm for histosols (a soil consisting primarily of organic materials) to 115 ppm for rendzinas (a dark, grayish-brown, humus-rich, intrazonal soil) Alina Kabata[1]. Govindaraju[4] reported the V content in reference soils of the U.S. within the range 36 to 150 ppm. The value of V in Wadi El Abde (44 ppm) lies within this last range.

Gallium (Ga)

The distribution of Ga in the soils of the study area shows some variation, in which the highest value is recorded in QI with 29.6 ppm. The values of Ga in QV and Wadi El Abde are 24.7 ppm and 23.3 ppm respectively, while the lowest value is recorded in QII with 21.1 ppm (TABLE 1).

The previous data are close to Alina Kabata[1]. He stated that, Ga is distributed rather uniformly in the major types of rocks and its common values in both magmatic and sedimentary rocks range from 5 to 25 ppm; but in ultramafic and calcareous rocks, the concentration of this metal is about 3 ppm. He also referred to average Ga content calculated for different soils of the U.S. to range from 11 to 30 ppm, being the lowest in sandy and calcareous soils and the highest in soils derived from granitic and volcanic rocks. The present range of Ga in the study area of N.E. Desert of Egypt (21-30 ppm) agrees well with the range of U.S. soils (11-30 ppm) according to Alina Kabata[1].

Chromium (Cr)

Chromium element distribution in the present soil samples shows some variations. The highest value is recorded in Wadi El Abde with 124 ppm, while the values in QI, QII and QV are nearly equal (44 ppm in QI and QV and 40 ppm in QII (TABLE 1). Alina Kabata[1] shows that concentration of Cr in acid igneous and sedimentary rocks commonly ranges from 5 to 120 ppm. The soil Cr is inherited from parent rocks and therefore its higher concentration is in soil derived from mafic and volcanic rocks. Thus the concentration of Cr from the four locations of the present study area is in agreement with Alina Kabata[1]. The present Cr range in our soils (40-124 ppm Cr) indicats that these soils are derived originally from acid igneous rocks or granites. A matter that expresses the real rock nature of the study area.

Tin (Sn)

Tin element distribution in the present soil samples shows some variations. The lowest value is recorded in QV with 4.0 ppm, while the values in QII, Wadi El Abde and QI are nearly equal (6.0 ppm in QII and Wadi El Abde and 7.0 ppm in QI) TABLE 1. Kick et al.[8] gave the range as 1 to 4 ppm. Govindaraju[4] reported that Sn contents in reference soils from China range from 2.5 to 17.7 ppm and in soils of the U.S. to range from 1.7 to 4.0 ppm. The allowable concentration of Sn in soils is established at 50 ppm. The values of Sn in the study area are in agreement with Govindaraju (op.cit.).

Distribution of elements in plant samples

This study deals with the accumulation and distribution of certain trace elements in *Fagonia boveana* plant and soil samples associated with them. Several heavy metals from contaminated soils are accumulated in plants Siedlecka[2], trans-located to above ground plant parts Marschner[9] and stored within different cell and tissue compartments Verkleij and Schat[10] and Ernst[21].

The ratio (Ep/Es) represents the concentration of a particular element in plant (ppm) over the concentration of the same element in soil. This ratio represents the uptake of a particular element from soil by plant and the average of this value in the four sites is called the Index.

Arsenic (As)

Fagonia boveana plant recorded the highest value for As ratio (As_p/As_s) in QI and Wadi El Abde with 0.62 and 0.77 respectively (TABLE 2). While the lowest value is recorded in QI location 0.08 (sample from up stream Alina Kabata). On the other hand, the value of the As ratio recorded with moderate value 0.36 is in QII location and 0.42 in QV location. The average for As element concentration in this plant is 0.47. The percentage ratio in this species is 47 %, which seems to be a significant value for this element.

Queirolo et al.[6] found that corn and potatoes, growing in a volcano-influenced location of Talabre (Northern Chile), contained high arsenic concentration in the edible parts (1.85 and 0.86 ppm fresh weight respectively), exceeding the National Standard of Chile for arsenic which is 0.5 ppm. TABLE 2 shows that *Fagonia* sp. for QI and Wadi El Abde locations gives 0.80 and 1.4 ppm As which are fairly close to Queirolo values. According to Mercedes Del Rıo et al., the ability of As absorption is 1.3 ppm by *P. oleracea* family Caryophyllaceae from Vicario site, Southern Spain. The present data shows that *Fagonia* sp. from Wadi El Abde site gives 1.4 ppm As which is close to Mercedes et al. value.

Bismuth (Bi)

Fagonia boveana shows the highest value of the given ratio in QI with 1.9 (TABLE 2). The lowest value is recorded in QII location with 0.07. Medium values

TABLE 2 : Concentration of As, Bi, V, Ga, Cr, and Sn (ppm) in ashes of *Fagonia boveana* plant samples and soil samples in Qattar area as well as (E p/E s) ratio

Plant Location		As		Bi		V		Ga		Cr		Sn	
Qatta I*	Plant	0.10	0.80	0.19	0.04	2.0	6.0	0.1	0.5	25.5	36.65	0.11	0.28
	Soil	1.3	1.3	0.1	0.1	5.0	5.0	29.6	29.6	44	44	7.0	7.0
	Ratio	0.08	0.62	1.9	0.4	0.4	1.2	0.003	0.016	0.58	0.83	0.02	0.04
Qattar II	Plant	0.50		0.02		4.0		0.3		39.96		0.17	
	Soil	1.4		0.3		5.0		21.1		40		6.0	
	Ratio	0.36		0.07		--		0.014		1.0		0.03	
Qattar V	Plant	0.50		0.03		3.0		0.3		3.51		0.21	
	Soil	1.2		0.1		5.0		24.7		44		4.0	
	Ratio	0.42		0.3		0.6		0.012		0.08		0.05	
Wadi ElAbde	Plant	1.4		0.05		12.0		1.2		107.15		0.35	
	Soil	1.8		0.2		44.0		23.3		124		6.0	
	Ratio	0.77		0.25		0.27		0.05		0.86		0.06	
IBA		0.47		0.44		0.55		0.02		0.66		0.04	
IBA %		47		44		55		2.0		66		4	
Av. Conc.		0.66		0.06		5.4		0.5		45.4		0.22	

Ratio Ep/Es: conc. of an element in plant/ conc. of the same element in soil; IBA : Index of bioaccumulation being the average of ratios in the four locations; Av. Conc: Average of concentrations of an element in plant from the four sites; All values except ratios are in ppm; * : Two samples are taken from this site.

of the ratio for Bi are recorded in QI (another sample) with 0.4, QV location with 0.3 and Wadi El Abde location with 0.25. The average ratio for Bi uptake in *Fagonia* sp. is 0.44. Accordingly the percentage ratio of Bi concentration in this plant is 44 %.

Vanadium (V)

The highest value for absorption ratio of V element in *Fagonia boveana* plant is 1.2 in QI location. The lowest value is 0.27 in Wadi El Abde location (TABLE 2). The moderate values of V absorption ratio are 0.4 for another sample in QI and 0.6 in QV. The mean of absorption for V ratio (V_p / V_s) in this species is 0.55 and the percentage ratio of V concentration therefore is 55 % which looks high. On the other hand, it is found that *Fagonia* sp. can concentrate V more when concentration of this element increases in soil. According to Khadija et al.[18], *Fagonia indica* can concentrate V with 6.89 ppm. In the present work *Fagonia* sp. concentrates 6.0 ppm in one sample in QI. Bonanno[7] stated that *Phragmites australis* sp. has the ability to absorb V with 9.20 ppm in root sample. In the present study *Fagonia* sp. recorded 12.0 ppm V in one plant sample collected from Wadi El Abde location. The present value is close to that recorded by Khadija and Bonanno.

Gallium (Ga)

Uptake of Ga element in *Fagonia boveana* recorded three levels for Ga uptake as given by the ratio (Ga_p / Ga_s). The high level is found in Wadi El Abde location with 0.05. The moderate level in QI, QII and QV locations is 0.016, 0.014 and 0.012 respectively (TABLE 2). The low level is found in another sample in QI (up stream sample) with 0.003. The mean of Ga absorption in *Fagonia* sp. is 0.02. Thus the percentage ratio of Ga concentration in this species is 2.0 %, it seems to be insignificant value for Ga element.

Chromium (Cr)

Uptake of Cr element in *Fagonia* species recorded three levels for Cr uptake as given by the ratio (Cr_p / Cr_s). The high level is 1.0 in QII location (TABLE 2). The low level is 0.08 in QV location. The moderate level is 0.83 in QI and 0.86 in Wadi El Abde location and 0.58 in another sample from QI. The average for Cr ratio in *Fagonia* species is 0.66, which mean that the percentage ratio for Cr absorption in this spieces is 66 %.

Tin (Sn)

Chemical analysis of Sn element in *Fagonia* plant shows nearly equal values of the absorption ratio in all locations with range from 0.02 to 0.06 (TABLE 2). The average of Sn uptake in *Fagonia* sp. is 0.04, and the percentage ratio of Sn accumulation in this species is 4 %.

Concerning *Fagonia* sp., the following brief notes are observed

1) It can concentrate the highest value of As (0.66 ppm). This plant can also accumulate As 16 times more than WPA (0.04 ppm) TABLE 3. It can be used for clearing soil from extra amounts of As element.
2) It is an important plant for concentrating Bi element (0.06 ppm) (TABLE 3). It can accumulate Bi 30 times more than WPA (0.002 ppm). It can be used as an index plant for exploration of Bi.
3) It is an important plant for accumulation of vanadium element (5.4 ppm) (TABLE 3). It can accumulate V 36 times more than WPA (0.15 ppm). This plant can be used for exploration of vanadium.
4) It is a somewhat important plant for absorption and concentration of gallium element (0.5 ppm), WPA not detected for this element. Thus it can be used for exploration for Ga.
5) It is a very important plant for absorption and concentration of Cr element (45.4 ppm). This plant can accumulate Cr 227 times more than WPA (0.2 ppm). An advice is given here to use this species for exploration of chromium deposits in the area.
6) It is an important plant for absorption and concentration of Sn (0.35 ppm in Wadi El Abde site). This plant can accumulate Sn 11 times more than WPA (0.02 ppm). Thus this plant can be used for exploration for tin.

TABLE 3 : Trace element concentrations in *Fagonia boveana* species from Qattar area and comparison with world plant averages

Element / Plant	As	Bi	V	Ga	Cr	Sn
Fagonia boveana	0.66	0.06	5.4	0.5	45.4	0.22
World Plant Av.*	0.04	0.002	0.15	Nd**	0.2	0.02

***:Berna et al.[20] after Reimann et al.[3]; **: Nd : not detected**

So, *Fagonia boveana* can be used as an indicator for As, Bi, V, Cr, Ga and Sn.

CONCLUSION

The distribution of the analyzed elements in soil samples of four localities indicates that:

1) Location QI has the highest concentration of Ga and Sn.
2) Location QII contains the highest concentration of Bi and Sn.
3) Location QV contains the high concentration of Ga.
4) Location Wadi El Abde has the highest concentration of As, V and Cr.

Fagonia boveana plant is condensed in the course of rainwater that is coming from top of Gebel Qattar (QI, QII and QV) toward vallies. Family name of this plant is called *Zygophyllaceae*.

Fagonia boveana is very important plant because it has the ability to absorb and concentrates: As, Bi, V, Ga, Cr, and Sn. Some of these elements are toxic though they absorbed by high values.

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