Mansoura Engineering Journal

Volume 40 | Issue 5 Article 23

12-1-2021

Phytoremediation of Some Polluted Soils by Sudan Grass (Sorghum Sodanese L.).

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Phytoremediation of Some Polluted Soils by Sudan Grass (*Sorghum Sodanese* L.)

علاج تلوث التربه باستخدام نبات حشيشه السودان

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الملخص

أجريت تجربه أصص فى قسم الاراضي كليه الزراعه جامعه المنصوره لدراسه تاثير استخدام حشيشه السودان فى علاج تلوث بعض انواع التربه فى محافظه الدقهليه. 10 بذور من نبات حشيشه السودان تمت زراعتها يوم 25 اغسطس 2014 و حصدت فى 10 اكتوبر 2014 فى انواع محتلفه من التربه والتى تم تجميعها من 10 اماكن متفرقه وملوثه بالعناصر الثقيله فى محافظه الدقهليه مثل (صرف صحى، مصانع، اماكن مرور، صرف زراعي ملوث) كما يلي: المنطقه المحيطه بمصنع سماد طلخا، المنطقه المحيطه بمحطه صرف صحي المنصوره، المنطقه المحيطه بمسابك المنصوره، طريق مصنه القمامه بسندوب، طريق مصنع راتنجات المنصوره، صرف زراعي بالسرو، طريق جديله بالقرب من معهد المنصوره، صرف صحى بميت الاكراد، طريق دكرنس (سلانت) و المنطقه المحيطه بمعهد السلاب.

النتائج المترتبه على هذه الدراسه اوضحت ان تركيز كل من الرصاص، النيكل و الكادميوم كان (6.00، 3.43 و 3.39 مجم\كجم) فى المجموع الخضري لحشيشه السودان والذي امتص واخذ كميه كبيره من الرصاص و النيكل و الكادميوم (192، 122 و 104 مجم\كجم نبات) فى المجموع الخضري اعلى من التركيز فى الجذري والتي سجلت (2.16، 2.78 و 2.13 مجم\كجم) و الممتص فى الجذري سجل (7، 9، 7 مجم\كجم نبات) من الاراضي الملوثه تحت الدراسه. ومن هنا يمكن القول ان المجموع الخضري لحشيشه السودان استخرجت وامتصت كميه اكبر من الرصاص، النيكل، والكادميوم عن المجموع الجذري وذلك يرجع للمجموع الخضرى الكبير للنبات. اوضحت النتائج ايضا ان عامل النقل سجل (2.77، 1.41 و 1.56) بينما البيولوجيكال كان اعلى من واحد (0.66، 0.78 و 0.72) لكل من الرصاص ، النيكل و الكادميوم على التوالى. فى النهايه يمكن التوصيه بان حشيشه السودان كانت اكثر فاعليه فى امتصاص وازاله العناصر الثقيل من التربه الملوثه وتعتبر مجمع عالى للعناصر الثقيله بمحافظه الدقهليه.

Abstract

A pot experiment was carried out in Soil Dep., College of Agric. Mans. Univ., to study the effect of using sudan grass for remediation of some polluted soils in Dakahlia governorate .Ten plant seeds per pot were sown on 25August,2014 and harvested on 10 October,2014. The experimental soils were taken from ten polluted locations to represent polluted soils in Dakahlia govrnorate from different sources i.e. (sewage, industry, traffic and agricultural drainage pollutions) as follows: Talkha fertilizer company adjacent area; El-Mansoura Sewage Station area; El-Mansoura Melting companies area; Town refuse - Sandob area; El-Mansoura Ratingat factory; El-Serw station Agric. Drainage; Gedilah road near El-Mansoura Institute; Sewage drainage - Meet El-Akrad area ; Sallant- Dekrnes road and El-Sallab Institute area. Data obtained from this investigation pointed out that the concentration of lead, nickel and cadmium were (6.00, 3.43 and 3.39 mg/kg) in sudan grass plant shoots which uptake and removed high values of lead, nickel and cadmium (192,122 and 104 mg/kg plant) shoots of Sudan grass plant than the roots (2.16, 2.78 and 2.13 mg/kg) and roots uptake (7.0, 9.0 and 7.0 mg/kg plant) from the studied polluted soils. It can be observed that; shoots of sudan grass extracted and absorbed more lead, nickle and cadmium than roots because this plant has a huge vegetative growth. Results, also showed that; translocation factor (2.77, 1.41 and 1.56) and biological accumulation factor were more than one (0.66,0.78 and0.72) for laed, nickle and cadmium, respectively. It can be concluded that; Sudan grass is more effective for remediation of these polluted soils in Dakahlia government and can be considered as a hyper accumulator for heavy metals.

Key words:

Phytoremediation, heavy metals, Sudan grass.

Introduction

Soil polluted with heavy metals is an increasingly urgent problem all over the world. Excessive concentration of heavy metals in soils often result from anthropogenic activities. On the other

Accepted: 24 June, 2015

hand, heavy metals enter into soil by various ways, such as atmospheric precipitation, by using chemical and manure fertilizers, compost, sewage, agricultural and industrial wastes and pesticides. The amount of entering these elements to agricultural lands depends on agriculture management. For example, the most important entry pathway of nickle to agricultural lands is phosphorous fertilizers and for cadmium and lead this way is sewage waste and agricultural and industrial waste and other industrial pollutants. In spite of differences in the behavior of heavy metals in soil, in terms of mobility and absorption, in most cases, it way possible that removal through leaching or uptake by the plants is much lower than the rate of their entry into the soil (**Kadkhodaie *et al.*, 2012**).

The food chain contamination resulting from plants containing particular heavy metals is a health risk to humans and animals. On the other hand, the uptake of trace metals by certain types of plants can be used as a natural clean-up process of soils (phytoextraction), though with a large economic impact.

Phytoextraction is a subset of phytoremediation in which metal-accumulating plants are used to transport and concentrate metals from soils into harvestable parts of roots and above ground shoots. Essentially, phytoextraction involves planting of successive crops of metal accumulating plants (*hyperaccumulators*) which extract the toxic metals from the soil into the above ground shoots **(Lasat, 2001**). However, hyperaccumulator plants usually have low growth rates and annual biomass production (**Salt and Kramer, 2000**). Slow growth rates limit their extraction capacity per unit soil surface, making the time required for an eventual site decontamination a critical factor in phytoextraction technology.

The use of crop plants for phytoremediation of contaminated soils has the advantages of their high biomass production and adaptive capacity to variable environments (**Komarek *et al.*, 2007**). However, to succeed they must be tolerant to the contaminants and be capable of accumulating significant concentrations of heavy metals in their tissues. Additionally, crops could make the long time-periods for decontamination more acceptable, economically and environmentally. If the concentration of contaminants in biomass is below critical levels for livestock consumption (**Murillo *et al.*, 1999**), crops could have an economic value during the phytoextraction process. Sudangrass is a kind of surghom, which is used for direct grazing and consumption as green grass. One of the good characteristics of this plant is resistant to heat and dryness and thus production of high biomass (**Maas and Hoffman, 1977**). Because pollution of soil with heavy metals which may be intensified in future, danger of increase in the absorption of heavy metals in plants will be higher (**Helal *et al*., 1996**). The aim of this study was how much suddan grass for remediation of these polluted soils. Lead, cadmium and nickle were extracted from the studied polluted soils.

Materials And Methods

1. Materials

1.1. Soil samples

Ten surface (0-30) soil samples were collected from different ten sites polluted with heavy metals due to different anthropogenic activities. These sites are:

1. Talkh fertilizer (S1).
2. Sewage station El-Mansoura (S2).
3. Metalluric El-Mansoura (S3).
4. Town refuse-Sandob (S4).
5. Ratingate factory ElMansoura (S4).
6. Agric. Drainage- El-Serw (S5).
7. Gdeilah road near El-Mansoura Ins. (S7).
8. Sewage drainage-Meet El-Akrad (S8).
9. Sallant-Dkerness (S9).
10. El-Sallab Ins. (S10).

The soils analyses are shown in Table(1)

1.2. Soil preparation and experimental setup:

To initiate this experiment, air-dried soils samples, sieved through 2mm sieve were used. The dimensions of the pot are 10 cm (diameter) × 20 cm (depth). Each pot contained 1 kg of air-dried soil. All pots were replicated 3 times.

In each pot 10 seeds were sown and placed 2-cm below the soil surface. Pots were waters so as to keep the soil moisture at limit of the water holding capacity by difference in weight. After 7 days from cultivation, plants were thinned to 5 seedlings per pot.

1.3. Plant samples:-

At harvest stage 40 days after planting of Sudan grass plants; 5 plants were taken from each pot; put in paper bags and carried immediately to the laboratory; the plant samples were oven dried at 70^{o} c till constant weight. Then, the dried plant samples were weighted (g/plant) and stored for chemical analysis.

1.4. Measured plant and soils parameters:-

- Ni, Pb, and Cd (mg/kg) in shoots and roots
- Shoot and root uptake of Ni, Pb, and Cd (mg/kg plant).
- Biological accumulation coefficient (BAC) calculated as follows according to (**Uchida *et al*. 2007**)

$$BAC = \frac{Heavy\ metals\ uptakes\ (mg/kg\ plant)}{Total\ content\ of\ heavy\ metals\ (mg/kg\ soil}$$

- Translocation factor (TF) calculated as follows according to **Fitz and Wenzel (2002)**

$$TF = \frac{Concentration\ of\ heavy\ metals\ (mg/kg\ \ plant\ of\ roots}{Concentration\ of\ heavy\ metals\ (mg/kg\ \ plant\ of\ shoots}$$

- Soil samples were taken from soils after cultivation to determined available Ni, Pb, and Cd (ppm).

Table 1: Some chemical and physical characteristics of the studied polluted soils sites

Parameters		Soils									
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Particale size distrbution %	C. sand	5.4	7.3	4.1	4.6	2.2	6.6	3.7	6.2	4.8	2.8
	F. sand	32.3	34.0	21.9	22.0	14.5	39.2	25.1	32.7	27.3	13.2
	Silt	35.9	37.4	34.3	35.8	33.5	31.7	30.9	36.4	35.8	36.1
	Clay	26.4	21.3	39.7	37.6	49.8	22.5	40.3	24.7	32.1	47.9
	T.class	S.C.L	S.C.L	C.L	C.L	Clay	S.C.L	C.L	S.C.L	Loamy	clay
%	W.H.C.	36.9	40.3	36.6	35.5	42.5	38.2	40.1	41.1	36.8	41.4
	O.M	1.60	1.31	1.93	1.84	2.36	1.42	2.09	1.49	1.72	2.24
	$CaCO_3$	3.41	4.09	2.57	2.82	4.86	3.88	2.31	3.65	3.10	2.03
	Porosity	42.1	35.7	50.4	49.2	55.8	37.6	52.3	40.2	46.3	54.9
B.D g/cm^3		1.41	1.49	1.30	1.34	1.21	1.48	1.24	1.45	1.39	1.23
EC soil past ext.		2.79	3.11	9.91	3.17	12.29	8.64	5.36	12.69	7.75	4.23
pH (1:2.5)		8.19	8.17	8.02	8.15	7.99	8.04	8.10	7.98	8.07	8.12
Ions meq / L	Ca^{++}	2.47	2.78	8.05	2.85	10.91	7.42	4.73	10.98	6.69	3.59
	Mg^{++}	1.86	2.03	6.41	1.98	8.79	6.63	3.65	8.92	5.16	2.52
	Na^{+}	7.61	8.47	28.21	8.50	32.96	22.97	14.56	34.44	20.90	11.91
	K^{+}	0.61	0.72	1.93	0.67	2.64	1.88	1.16	2.76	1.65	0.98
	$CO_3^{=}$	-	-	-	-	-	-	-	-	-	-
	HCO_3^{-}	2.69	2.91	8.29	3.07	11.22	7.80	4.95	11.37	7.03	3.81
	Cl^{-}	7.13	8.09	27.75	7.98	30.44	20.85	13.19	33.75	19.57	10.16
	$SO_4^{=}$	2.73	3.00	8.56	2.95	13.64	10.25	5.96	11.98	7.80	5.03
Available mg/kg soil	N	58.2	48.9	68.2	64.8	79.6	51.7	72.3	55.1	61.4	76.5
	P	11.8	7.9	16.7	14.8	21.4	8.7	18.1	10.3	13.6	19.5
	K	241.7	198.2	282.3	269.4	316.4	212.7	295.6	226.3	256.8	307.1
	Pb	6.32	5.67	4.85	5.58	6.80	5.11	8.33	5.24	7.71	7.29
	Ni	5.03	5.82	4.45	3.39	3.05	4.67	3.76	5.51	2.77	3.98
	Cd	3.86	3.21	3.66	3.38	3.02	2.80	1.95	3.52	2.51	2.19
Total content	Pb	94.8	85.05	72.75	83.7	102	76.65	124.95	78.6	115.65	109.35
	Ni	60.3	58.2	54.5	33.9	30.5	46.7	57.6	55.1	27.7	59.8
	Cd	19.3	16.05	18.3	16.9	15.1	14	9.75	17.6	12.55	10.95

2. Methods:

2.1. Soil analysis:

- The electrical conductive (EC) of the saturated soil paste extract was measured by EC meter according to the method of **Jackson, (1967).**
- Water holding capacity (W.H.C) was determined according to **Black, (1965).**
- Soil reaction (pH) was measured in 1: 2.5 soil water suspension as described by **Jackson, (1967).**
- Soil particle size distribution was determined following the international pipette method using NaOH as a depressing agent as described by **Dewis and Fertais, (1970).**
- Total calcium carbonate was determined using Collin's calcimeter method according to **Dewis and Fertais, (1970).**
- Organic matter (O.M) content was determined using **(modified Walkely Black method)** described by **Mathieu and Pieltain, (2003).**
- Porosity (P %) was calculated according to **(Nimmo, 2004).**
- Available N was determind using the conventional method of Kjeldahl as described by **Bremner and Mulvany, (1982).**
- Available P was extracted with 0.5 M ($NaHCO_3$) adjusted at pH 8.5 and determined at a wavelength 660 nm by Spectrophotometer as described by **Olsen and Sommers, (1982).**
- Available K was determined by extracting with ammonium acetate at pH 7 and measured using a flam photometer according to **Hesse, (1971).**
- For available heavy metals content determination in the soil; Cd, Ni and Pb were extracted with diethylene-triamine-penta acitic acid (DTPA). The solution is made up of a mixture For available heavy metals content determination in the soil; Cd, Ni and Pb were extracted with diethylene-triamine-penta acitic acid (DTPA). The solution is made up of a mixture of 0.005 M DTPA, 0.1 M triethanolamin (TEA) and 0.01 M $CaCl_2$**,** adjusted to pH 7.3. The concentrations in extracts were determind using an atomic absorption spectrophotometer; model of VARIAN specter AA. 20 according to **Mathieu and Pieltain, (2003).**
- Total content of Cd, Ni and Pb in soil determined by fujion with sodium carbonate and dissolving in HCl 6.0 N and estimated by Atomic absorption as described by **Jackson, (1967).**

2.2. Plant analysis:

For estimation of heavy metals; Cd, Ni and Pb were extracted from the plant samples using the method of micro wave digestion. 0.1 g from each sample was homogenized in a Teflon cups with 5 ml nitric acid (ultrapure), 2 ml H_2O_2 30 % and 0.5 ml hidro floric acid. The mixture was put in microwave apparatus at 37 wt/12min. the mixture was frozen at – 10 ^{o}C / 30 min and set up at 50 ml with redistilled water. The concentrations of heavy metals was detrmined by electrothermal atomic absorption spectrometery, Perkin elmer Model 5100 as described by **Kumpulainen *et al.*, (1983).**

3. Statistical analysis:

All data were statistically analyzed according to the technique of analysis variance (ANOVA) and the least significant difference (L.S.D) method was used to compare the deference between the means of treatment values to the methods described by **Gomez and Gomez, (1984)**. All statistical analyses were performed using analysis of variance technique by means of **CoSTATE** Computer Software.

Results and Discussion

1-Dry weight of sudan grass shoots and roots:

Data in Table (2) show a significant variation among values of dry weights for both roots and shoots due to the situation and pollution occurred in each soil sample. Results in Table (2) show that Sudan grass has a huge vegetative growth for shoot compared to root system. The values of over ground part of Sudan grass ranged between 32 amd38 g-plant after40 days from planting.

Table 2: Sudan grass dry weight of shoots and roots as affected by site of polluted soil samples:

Treatments	Dry weight of shoot (g/pot)	Dry weight of root (g/pot)
Talkha fertilizer	32.04	3.18
Sewage station El-Mansoura	27.96	2.70
Metalluric El-Mansoura	25.22	2.43
Town refuse; Sandob	30.74	3.02
Ratingat factory El-Mansoura	**33.58**	**3.35**
Agric. Drainage; El-Serw	**29.44**	**2.85**
Gedilah road near El-Mansoura Ins.	**38.18**	**3.89**
Sewage drainage; Meet El-Akrad	**26.70**	**2.54**
Sallant; Dekrnes	**36.22**	**3.71**
El-Sallab Ins.	**34.56**	**3.53**
Mean	**31.46**	**3.12**
$LSD_{at\ 5\%}$	**1.63**	**0.33**

2-Uptake of heavy metals of shoots and roots:

This part of study focused on heavy metals phytoremediation by suddan grass plant grown on the different soils which polluted with heavy metals.

The obtained results given in Table 3 show the uptake of Pb, Cd and Ni mg/kg plant in shoots and roots from different studied soils, the pattern of accumulation of all these metal ions was different as far as plant parts are concerned. Date in table show the uptaked of Pb, Cd and Ni mg/kg plant in Sudan grass shoots and roots were significantly correlated with situation of different sits. Data obtained from this investigation pointed out that; shoots of Sudan grass plant absorbed and uptake more lead, cadmium and nickle (192, 122 and 104 mg/kg plant) in shoots than the roots (7.0, 9.0 and 7.0 mg/kg plant) from the studied polluted soils. It can be observed that; shoots of sudan grass extracted and absorbed more lead, nickle and cadmium than roots because this plant has a huge vegetative growth and its season is long, therefore it can remove excessive amount of Ni, Cd and Pb from studied polluted soils.

3-Exrtactable Pb, Cd and Ni from studied polluted soils:

Data presented in Table 4 show values of extractable Pb, Cd and Ni mg kg^{-1} soil. Values of available Pb ranged from 7.97 in Metalluric El-Mansoura soil to10.09 in Gedilah road near El-Mansoura Ins. Soil. Thes soils were polluted with Pb from sewage waste and agricultural and industrial wastes and other industrial pollutants. As for Cd in their soil flocculated between 4.73 in Sallant; Dekrnes and 6.16 mg kg^{-1} in El-Mansoura sewage station site. The pollution of these soils with Ni as pollutant is due to application of phosphate fertilizers. Extractable Ni content was ranged between 3.62 in El-Sallab Ins. soil and 5.09 mg kg^{-1} in Talkha fertilizer soil. The mean Pb values of these heavy metals there found to be higher than Cd or Ni.

The extractable form of heavy metals indicate the easily and ready part for absorption by part roots and subsequently cleaning up polluted soils from heavy metals having high levels.

The natural level for studied heavy metals in soil are 90 ,0.8 and 50 $mg.kg^{-1}$ for Pb ,Cd and Ni, respectively, while maximum acceptable levels for them are 150,5 and100 $mg.k^{-1}$,respectively according to Dutch model to evaluate the pollution hazard as mentioned by Lacatusu, (1998).

Concerning to the results in Table 1 some sites have values exceed these levels such as S1,S3, S6 and S10 for Ni and S1, S5, S7, S9 and S10 for Pb while all investigated soils are pollute with Cd.

Table 3: The uptake of some heavy metals roots and shoot of Sudan grass grown on studied polluted soils

Treatments	Pb, $mg.kg^{-1}$ plant	Cd, $mg.kg^{-1}$	Ni, $mg.kg^{-1}$
Roots			
Talkha fertilizer	7.091	9.487	7.908
Sewage station El-Mansoura	5.256	8.550	5.841
Metalluric El-Mansoura	4.305	6.916	5.884
Town refuse; Sandob	6.345	7.681	6.797
Ratingat factory El-Mansoura	7.727	8.386	7.001
Agric. Drainage; El-Serw	5.786	8.293	5.747
Gedilah road near El-Mansoura Ins.	9.712	10.249	6.896
Sewage drainage; Meet El-Akrad	4.800	7.883	5.969
Sallant; Dekrnes	9.052	8.843	7.160
El-Sallab Ins.	8.448	9.689	6.421
Mean	6.852	8.598	6.562
$LSD_{at\ 5\%}$	0.725	0.981	0.693
Shoots			
Talkha fertilizer	193.519	135.206	120.792
Sewage station El-Mansoura	150.892	126.009	93.568
Metalluric El-Mansoura	125.427	99.906	92.631
Town refuse; Sandob	180.980	112.233	106.691
Ratingat factory El-Mansoura	212.894	118.647	110.026
Agric. Drainage; El-Serw	165.646	120.509	94.407
Gedilah road near El-Mansoura Ins.	272.996	142.185	112.525
Sewage drainage; Meet El-Akrad	138.127	114.990	95.141
Sallant; Dekrnes	249.310	123.507	112.639
El-Sallab Ins.	224.696	135.167	104.683
Mean	191.449	122.836	11.55
$LSD_{at\ 5\%}$	22.18	11.79	0.006

Table 4: Extractable contents of heavy metals in the investigated soils.

Treatments	Pb, $mg\ kg^{-1}$	Cd, $mg\ kg^{-1}$	Ni, $mg\ kg^{-1}$
Soil			
Talkha fertilizer	8.96	5.89	55.09
Sewage station El-Mansoura	8.37	6.16	54.42
Metalluric El-Mansoura	7.97	5.56	54.91
Town refuse; Sandob	8.76	5.01	54.65
Ratingat factory El-Mansoura	9.30	4.82	54.23
Agric. Drainage; El-Serw	8.66	5.71	3.97
Gedilah road near El-Mansoura Ins.	10.09	5.12	3.41
Sewage drainage; Meet El-Akrad	8.18	6.05	4.77
Sallant; Dekrnes	9.81	4.73	3.81
El-Sallab Ins.	9.52	5.31	3.62
Mean	8.96	5.43	29.29
$LSD_{at\ 5\%}$	0.08	0.10	0.09

4-Translocation factor and biological accumulation factor:

Results obtained in Table 5 revealed the translocation factor of Pb, Cd & Ni, data showed that translocation factor values are 2.77, 141 and 1.56 for Pb, Cd and Ni, respectively.

Dube *at al.*, (2004) suggested that the ratio between metal concentration in plant and soil is an important criterion for selecting plant species for phytoremediation of soils polluted with high levels of heavy metals. Results cleared that higher concentration in plant parts than soil might identify sudan grass as a hyper accumulator plant.

In the same Table the biological accumulation factor values showed that suddan grass plant very high affinity for Pb, Cd & Ni uptake and accumulation in their shoots and roots. With respect to mean accumulation of Pb, Cd & Ni (0.66, 0.78 and 0.72), respectively.

Biological accumulation coefficient (BAC) values for Pb, Cd and Ni are more than one for all polluted sites of study. Such results indicated high absorption uptake of these heavy metals in sudan grass. On the same trend, translocation factor (TF) values were more than one which express high translocation of Pb, Cd and Ni from roots to shoots to be accumulated and in other words more removing and extraction of these elements from studied soils to be less pollution and more healthy.

Table 5: Translocation factor and biological accumulation coefficient of heavy metals in the studied polluted soils.

Treatments	Pb	Cd	Ni
TF			
Talkha fertilizer	2.709	1.415	1.516
Sewage station El-Mansoura	2.773	1.423	1.547
Metalluric El-Mansoura	2.810	1.394	1.515
Town refuse; Sandob	2.800	1.435	1.542
Ratingat factory El-	2.749	1.412	1.568
Agric. Drainage; El-Serw	2.774	1.407	1.592
Gedilah road near El-	2.860	1.415	1.660
Sewage drainage; Meet El-	2.744	1.388	1.516
Sallant; Dekrnes	2.822	1.432	1.612
El-Sallab Ins.	2.716	1.427	1.669
Mean	2.776	1.415	1.574
BAC			
Talkha fertilizer	2.116	2.877	6.668
Sewage station El-Mansoura	1.836	2.312	6.194
Metalluric El-Mansoura	1.783	2.400	5.383
Town refuse; Sandob	2.238	3.537	6.715
Ratingat factory El-	2.163	4.165	7.750
Agric. Drainage; El-Serw	2.237	2.758	7.154
Gedilah road near El-	2.263	4.054	12.248
Sewage drainage; Meet El-	1.818	2.230	5.745
Sallant; Dekrnes	2.234	4.778	9.546
El-Sallab Ins.	2.132	3.640	10.146
Mean	2.082	3.275	7.755

Conclusion

The Sudan grass is recommended for phytoremediation of these polluted soil taken from different sites in Dakahlia governorate.

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