

## **USING PHYTOREMEDIATION AS A TOOL FOR IMPROVING A PETROLEUM HYDROCARBON CONTAMINATED SOIL**

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### **ABSTRACT**

Phytoremediation of petroleum hydrocarbon contaminated soils presents promising technology for environmental clean up using in situ treatment, especially in the developing countries. In the present study, the rhizospheric and non rhizospheric soil samples was collected from three different locations which were non contaminated, contaminated by crude oil untreated and contaminated by crude oil grown with different plants respectively, these location are in the same zoon area at Kafr Al-Elow Helwan city, Cairo governorate, Egypt.

Results showed that the concentration of Cu, Zn, Fe, Mn, Cd, Ni, Pb in surface soil polluted (0-30 cm) by crude oil were increased to 4.1, 2.2, 6.9, 2.1, 4.2, 7.8 and 6.1 times, respectively, compared to unpolluted soil because of the crude oil pollution is often accompanied by the presence of high levels of heavy metals. Also, this increasing reduced with soil depth due to their low mobility.

The highest loses in concentration of heavy metals and PAHs was recorded in the rhizospheric soil which planted with Alfalfa then Wheat followed by Sorghum respectively, thus the legume plants were suitable candidates for phytoremediation of soils contaminated with PAHs pollutants.

On the other hand, the results indicated that the translocation of PAHs from root to shoot was considerably restricted, and the disparities of shoot PAHs concentrations for various plant species grown in soil polluted may be due to the shoot uptake of PAHs and accumulation from the ambient air, possibly originally volatilized from the soils, was an important pathway for these PAHs intake by vegetable.

In the pot experiment, Faba bean plants was able after 65 days to reduce total Acenaphthene, Phenanthrene and Pyrene in the rhizospheric soil from 297.8, 21.0 and 251.3 to 51.8, 4.3 and 84.37 mg kg<sup>-1</sup> soil respectively, (i.e. 82.6, 79.5 and 66.3 % loss).

**Keywords :** Phytoremediation, petroleum hydrocarbon, PAHs, heavy metals legume and monocot plants.

### **INTRODUCTION**

The main problems of the environmental pollution in urban and rural Egypt include the disposal of solid and liquid waste, including hazardous materials, air pollution, the purity of the water supply, pests, noise levels, the enduring presence of harmful chemicals originally used as pesticides and fertilizers. (Watts and El Katsha, 1997). Environmental pollution was increased by increasing the industry development all over the world and especially in Egypt; increment of these pollution caused many hazards for all organisms, even for humans such as carcinogenicity and toxicity. Also, there has been increasing pollution with hydrocarbon compounds, many of these hydrocarbons considered to be a potential health hazard (Sepic *et al.*, 1996

and Hafez *et al.*, 2008). Millions tons of hazardous and non-hazardous wastes are generated each year in Egypt (Bayoumi, 2009).

Soil contamination with Petroleum hydrocarbons causes extensive damage to local ecosystem since accumulation of such pollutants in tissues of animals and plants may cause death or mutation. Petroleum is a complex mixture made of thousands of compounds which can be divided into 4 major fractions : the alkanes, the aromatics, the resins and the asphaltenes. The aromatics especially the recalcitrant polycyclic compounds (PAHs) are of concern owing to their toxicity and tendency to bioaccumulation (Kalf *et al.*, 1997). Petroleum oil and petrochemicals include significant amount of polycyclic aromatic hydrocarbons (PAHs), (Oleszczuk and Baran, 2005).

The fate of PAHs in nature is a great environmental concern due to their toxic, mutagenic and carcinogenic properties. Their environmental importance led US-Environmental Protection Agency (US-EPA) to identify 16 unsubstituted PAHs as priority pollutants, 8 of which are possible human carcinogens, (Antizar-Ladislao *et al.*, 2006). There are many industrial areas exist as a result of different crude oil activities which produce large amount of polycyclic aromatic hydrocarbons (PAHs) in Egypt, which represent severe hazards effects on the ambient environment. (Laila farahat and El gendy, 2008 and Abd-Elsalam *et al.*, 2009). Polycyclic aromatic hydrocarbons (PAHs) are a large group of organic compounds with two or more fused aromatic rings in linear, angular, or cluster arrangements. They have a relatively low solubility in water, but are highly lipophilic character and resistance to biodegradation, (Johnsen *et al.*, 2005 and Hafez *et al.*, 2008). High molecular weight PAHs, i.e. PAHs with four or more condensed aromatic rings, are considered to be more dangerous than two and three rings PAHs in view of their higher genotoxic potentials (Yang and Silverman, 1988). According to the criteria established by Maliszewska-Kordybach, (1996), four classes of soil contamination were identified based on a total of 16 PAHs : non contamination soil (< 200 ppm), weakly contaminated soil ( 200 - 600 ppm) contaminated soil ( 600 - 1000 ppm) and heavily contaminated soil (> 1000 ppm ).

One of the serious problems for decontamination biotechnology is the existence of mixed pollution, i.e., the simultaneous presence of pollutants of different groups in soil. Near motorways or industrial facilities, soil contamination with PAHs is often accompanied by the presence of high levels of heavy metals (Koeleman *et al.*, 1999 and Adeniyi and Afolabi, 2002) . An extensive literature is available on the effect of heavy metals on microbial population and microbial processes such as litter decomposition and carbon mineralization. However, little is known about the effect of heavy metals on the degradation of recalcitrant hydrocarbons, such as PAHs. Some heavy metals are thought to be essential for oil-degrading microorganisms while others are known to be toxic. Whereas some metals, such as copper, are essential for bacteria and fungi in trace amounts, high concentration are known to be toxic. The addition of copper to the soil significantly inhibits soil respiration, nitrogen mineralization and nitrification (Atagana, 2006). Heavy metals like cadmium, copper, or mercury are known to be toxic for both white-rot fungi (Mandal, *et al.*, 1998) and soil microflora (Burkhardt, *et al.*, 1993)

and their negative effect on the activity of ligninolytic enzymes has been described under in vitro conditions. The presence of these substances in the environment can therefore negatively influence the effectiveness of bioremediation technologies (Baldrian, *et al.*, 1996).

A village relying primarily on agriculture as Kafr Al-Elow Helwan, city Cairo governorate, Egypt, has a serious problem with air and canal water. Air pollution is perceived as a problem, particularly in Kafr Al-Elow because of the nearby cement plant and other industries. Burning garbage and automobile exhaust also add to air pollution, in addition to the 'natural' dust derived from Cairo's desert situation. Recently, a catastrophe natural was happened in this village nearing petroleum refinery situation which a crude oil tub was explosive, greatly of agricultural soils were flooded by crude oil particularly around this situation. Some of farmer's quit these soils contaminated in lieu of payment and the others farmers are trying reclaims this contaminated area with some traditional methods (i.e. whishing, draying, tillage and planting) thins 2-3 years ago without significantly improvement, according to tacking with farmers.

Finally, the advantages of phytoremediation compared with other approaches are as follows: (1) it preserves the natural structure and texture of the soil; (2) energy is derived primarily from sunlight; (3) high levels of microbial biomass in the soil can be achieved; (4) it is low in cost; and nevertheless many limitations exist for large-scale application of this technology (US EPA, 2000; Suthersan, 2002 ; Joner *et al.*, 2004). The objective of this work is to study the effects of the phytoremediation by using a legume plants (Faba bean and Alfalfa) and monocot plants (Sorghum and wheat) on improving a petroleum hydrocarbon contaminated soil, through the degradation of PAHs compounds in this polluted soil.

## **MATERIALS AND METHODS**

To achieve the main objective of this research, experiments were carried as follows:

### **Soil location**

Three different locations were chosen from Kafr Al-Elow village Helwan, city Cairo governorate, Egypt. The first location was represented by one sample which collected from soil surface of uncontaminated by crud oil in the same area (control). The second location was represented by 4 samples for 4 different layers of soil flooded by crud oil and untreated by farmers. The third location was represented by rhizospheric soil samples of soil flooded by crud oil and treated with traditional methods by the farmers and using different species of plants as phytoremediation technique i.e. Alfalfa, (*Medicago Sativa*, L.) ; Sorghum, (*Sorghum Vulgare* ) and wheat (*Triticum aestivum*), number of these rhizospheric soil samples equals for the number of sowing plants under this conditions. Soil samples collected from these locations at June approximately at the end of age plant to determine the total of heavy metals and PAHs residual in these locations. Also, plant samples were taken at the same time for analyses to study the effect of this polluted

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soil on elements and hydrocarbons compounds accumulations and translocation in or to these plants.

According to the method described by Jackson (1973), 1.0 g of homogenized soil sample was digested with 12.5 ml of aqua regia ( $\text{HNO}_3$  :  $\text{HCl}$  :  $\text{HClO}_3$  with a ratio 3:1:1), the samples were heated until the color become clear, dissolved with several drops 1%  $\text{HNO}_3$ , filtered, diluted to a volume of 50 ml with distilled water, and analyzed for the total content of heavy metals using flame atomic absorption spectrophotometer. The total hydrocarbons concentrations were determined gravimetrically (Viguri *et al.*, 2002), ten grams of the air-dried soil samples were mixed with 10 grams of anhydrous sodium sulphate to remove moisture. The hydrocarbons were Soxhlet extracted using a mixture of n-hexane and dichloromethane (1:1v/v). Samples of different plants, shoot and roots were collected, dried at  $70^\circ\text{C}$ , crushed and wet digested using mixture of  $\text{H}_2\text{SO}_4$  +  $\text{HClO}_4$  acids to determine heavy metals contents in aliquots of the digested solutions, (Ryan *et al.*, 1996). Plant shoot and root samples (100~200 mg dry weight) were ground and extracted for 4 h with 200 ml chloroform. The extracts were concentrated to 0.5 ml and analyzed on HPLC as described by Szolar *et al.*, (2002).

Identification and quantification of the individual polycyclic aromatic hydrocarbon (PAHs) were determined using Chromopack CP 9001 gas chromatograph equipped with a CP 9050 liquid samples and configured with FID, using helium as a carrier gas, with a flow rate of  $1\text{ ml min}^{-1}$ . CP sill 19CB Colum (25 m length x 0.32 mm diameter x 0.2  $\mu\text{m}$  thickness for the stationary phase) was used. Temperature programming of initial holding at  $40^\circ\text{C}$  (2 min), and then heating with a rate of  $10^\circ\text{C min}^{-1}$  to  $250^\circ\text{C}$  (holding 2 min) was applied. The total time of analysis was 45 min. Injector and detector temperature were  $250^\circ\text{C}$  and  $280^\circ\text{C}$  respectively. Injection volume was 1  $\mu\text{l}$  for all samples. The quantification of PAHs was based on application of reference standard (obtained from Supelco Co.) contained a mixture of the 16 priority PAHs ( $100\text{ mg kg}^{-1}$  for each individual).

#### **Pot experiment**

Soil using in this experiment were carefully collected from the root zone soil contaminated which treated with traditional methods. At the beginning of the experiment, soil sample were air dried, homogenized, sieved through 20 mesh and was analyzed at zero time. The soil of the pot experiment was clay loam in texture (C. Sand, 2.37 %; F. sand, 31.21 %; Clay, 35.09 % and Silt, 31.33%) with pH of 7.2, EC (dc/m) 1.52, organic matter, 2.6 % and containing  $1400\text{ mg kg}^{-1}$  of PAHs.

#### **A pot experiment examined having the following treatments:**

- 1) Soil polluted unplanted and untreated. (Control.)
- 2) Soil polluted unplanted, treated with NPK (recommended rates), and microbe-inhibited (0.5%  $\text{HgCl}_2$  was used to inhibit the microbial activity),
- 3) Soil polluted unplanted treated with NPK (recommended rates), without added microbe-inhibited.
- 4) Soil polluted was planted with legume plant Faba bean (*Vicia faba*), with NPK fertilizers (recommended rates).

Seeds of Faba bean plants were grown in black plastic pots for the forth treatment. Three replications per each treatment were used to give total 12 pots used in this investigation. Each pot containing 1kg of this soil polluted, moisture was added (50% of the water holding capacity). After 65 days growth period of plant, soil samples were taken from each pot to determine the residual hydrocarbons PAHs. Also, plant samples were collected and separated to shoot and root, dried at 60°C and kept for further studies to detect if PAHs are accumulated in plant tissues or not. This pot experiment aims to quantify the dissipation amount and dissipation ratio of PAHs (i.e. acenaphthene, phenanthrene and pyrene ) from the soil polluted, as consequence to bioremediation processes or phytoremediation technique.

## RESULTS AND DISCUSSION

Data in Table (1) observed that concentration of all total heavy metals and total PAHs were very highly in the second and the third location compared with the first location which is far from the source of pollution (accidental natural). In the second location, the concentrations of Cu, Zn, Fe, Mn, Cd, Ni and Pb in surface soil polluted (0-30 cm) were increased to 4.1, 2.2, 6.9, 2.1, 4.2, 7.8 and 6.1 times compared to the first location unpolluted respectively. These results indicates that crud oil pollution is often accompanied by the presence of high levels of heavy metals, and suggests that this highly increasing in concentration of heavy metal has negative effect on degradation of PAHs, this effect my be due to decreasing the microbial population and microbial processes (Atagana, 2006). Also, the highly contaminated with crud oil especially in surface soil has hazards on microbial population activity and soil physical properties which prevents the aeration, oxidation and mineralization of these compounds, so that more time may be required to phytoremediate a site, and may need several years.

**Table (1): Heavy metals and hydrocarbons contents in different soil location.**

Location	Depth (Cm)	phytoremediation technique	Total heavy metal contents (mg kg <sup>-1</sup> )							Total PAHs (mg kg <sup>-1</sup> )
			Cu	Zn	Fe	Mn	Cd	Ni	Pb	
The first location	SNC (0-30 cm)	Control	19	71	1322	265	0.9	3.5	12	182.7
The second location	0 - 5 Cm	Untreated	86	209	22423	756	3.8	28.5	78	34281
	5 - 10 Cm		78	158	5640	582	4.0	26.3	78	29225
	10 - 20 Cm		80	130	4308	473	3.7	29.0	70	20564
	20 - 30 Cm		70	118	4265	437	3.5	25.3	66	12320
The third location	Rhizospheric soil	Treated with Alfalfa	38	141	1535	318	1.9	12.8	39	1400
		Treated with Sorghum	45	148	1620	325	2.2	14.8	41	2625
		Treated with wheat	41	144	1570	320	2.0	14.1	40	2250

In the second location, data presented in Table (1) showed that the concentrations of heavy metals and PAHs decreased with increasing soil depth, these results my be due to their presence in phase complex are limited

mobility by their low water solubility in addition to adsorption onto soil colloids, precipitation and interaction with organic ligands (McBride, 1989). On the other hand, the results of rhizospheric soil analyses for the third location indicated that the level of heavy metals and PAHs were reduced with vegetation. The highest reduction in these polluted was recorded with planting Alfalfa then Wheat and Sorghum respectively, which the highest percent loses in concentration of Cu, Zn, Fe, Mn, Cd, Ni, Pb and PAHs recorded approximately by 51.6, 8.3, 83.2, 43.4, 49.3, 53.1, 46.6 and 94.2 % respectively under phytoremediation processes. The above results showed that the legume plant Alfalfa stimulated more reduction value of PAHs compounds (94.2%) as compared to the two monocot plants; Sorghum and wheat. This may be due to the ability of Alfalfa roots to fix atmospheric nitrogen and can be exude certain enzymes to degrade or transform the pollutants ( Liu *et al*, 2004), in addition to the ability of this species to tolerate up to 10% (w/w) crude oil (Emani Diab 2008). On the other hand the advantage of the chosen monocot plants is their extensive branching of the fibrous root system, resulting in a large root surface area per unit volume of surface soil. The fibrous roots would provide a larger surface for colonization by soil microorganisms than a tap root (White *et al*, 2006), for this reason, the reduced values of PAHs in root zoon (rhizospheric soil) were 89.1 and 90.7 % for Sorghum and wheat respectively. This results my be due to not only the phytoremediation or bioremediation processes in this season but due to others processes through 2-3 years ago included; flooding by water, leaching, draying, tillage, a biotic dissipation, biodegradation and plant uptake and accumulation.

**Table(2):Accumulation of heavy metals and PAHs in different species of plants.**

Species of plants	Partes of plants	Heavy metals contents (mg kg <sup>-1</sup> dry weight)							Total PAH (mg kg <sup>-1</sup> dry weight)
		Cu	Zn	Fe	Mn	Cd	Ni	pb	
Alfalfa	Shoots	38	93	235	121	0.41	3.10	10.20	5.14
	Roots	44	123	341	191	0.75	4.40	17.90	492
Sorghum	Shoots	33	81	245	111	0.35	2.70	9.30	2.77
	Roots	38	112	298	187	0.87	4.10	12.40	375
Wheat	Shoots	32	88	221	119	0.31	2.90	9.80	3.38
	Roots	40	116	277	173	0.55	4.30	12.90	381

Concentration of heavy metals and PAHs in shoots and roots for different plants grown in soil polluted by crud oil were presented in Table (2), the dry weight content indicated that the ability of these different plants to accumulate these polluted particularly in roots. The above results in Table (2) show that the concentrations of PAHs in shoots were significantly lower than in roots particularly in legume plant Alfalfa compared to monocot plants Sorghum and wheat. These results indicated that the transfer of PAHs from root to shoot was considerably restricted, and the disparities of shoot PAHs concentrations for various plant species grown in soil polluted may be due to the shoot uptake of PAHs and accumulation from the ambient air, possibly

originally volatilized from the soils, was an important pathway for these PAHs intake by vegetable.

The results in Table (3) demonstrate the resolution of the 16 US EPA priority PAHs in soil polluted used in pot experiment (at-0-time). As a total the sum of the initial 16 compounds was 1400 mg kg<sup>-1</sup> soil. The results show that acenaphthene and pyrene were more frequent than the other PAHs (21.3% and 18 % respectively). This was followed by flourene (12.8%), acenaphthylene (8.4%), benzo (K) flouranthene (7.4%), benzo (ah) anthracene (7.2%) and anthracene (6.4%). Other PAHs are of lower frequency, they are in the range of 0.4% - 4.7%. These results are different from location to other corresponding source of crud oil pollution and remediation condition.

**Table (3): Identification and quantification of the individual polycyclic aromatic hydrocarbon (PAHs) in soil polluted used in pot experiment (at-0-time):**

PAHs	No. of rings	mg kg <sup>-1</sup> soil	%	S <sub>w</sub> * (mg.L <sup>-1</sup> )
1 Naphthalene	2	5.9 + 0.8	0.4	31.0000
2 Acenaphthylene	3	117.6 +10.1	8.4	3.9300
3 Acenaphthene	3	297.8 + 4.3	21.3	1.9300
4 Flourene	3	179.3 + 22.1	12.8	1.8500
5 Phenanthrene	3	21 + 1.2	1.5	1.2000
6 Anthracene	3	89.9 + 3.2	6.4	0.0750
7 Flouranthene	4	38.4 + 2.8	2.7	0.2300
8 Pyrene	4	251.3 + 14.1	18.0	0.0770
9 Benzo(a) anthracene	4	66 + 3.5	4.7	0.0100
10 Chrysene	4	14 + 0.1	1.0	0.0028
11 Benzo (b) flouranthene	5	16.8 + 0.1	1.2	0.0012
12 Benzo (k) flouranthene	5	103.8 + 0.5	7.4	0.0008
13 Benzo (a) pyrene	5	16.7 + 0.2	1.2	0.0023
14 Dibenzo (ah) anthracene	5	101.1 + 3.7	7.2	0.0005
15 Benzo (ghi) perylene	6	52.1 + 1.1	3.7	0.0003
16 Indeno (1,2,3-c,d) pyrene	6	25.9 + 1.8	1.9	0.0620
<b>Total</b>		<b>1397.6</b>	<b>99.8</b>	<b>40.3718</b>

S<sub>w</sub>\* = means of solubility in water which were collected from several literatures and statistically analyses by Amer, (2006)

Data in Table (3) show the aqueous solubility of the US EPA priority pollutant PAHs range from 31 mg.L<sup>-1</sup> for naphthalene (MW = 128) to 3x 10<sup>-4</sup>

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mg.L<sup>-1</sup> for benzo (g.h.i) perylene (MW = 276), these means of aqueous concentration of an individual PAHs plays a significant role in various physical and biological processes (Amer, 2006), which the compounds that have a lowest solubility are the lowest mobility and highest resistant in the environment. Also, the decreasing in aqueous concentration of an individual PAHs were combined with increasing this molecular weigh (MW) and difficulty the degradation process.

The quantification of the loss (%) of the 3 PAH individual for studied treatments were presented in Table (4) The rhizospheric soil for Faba bean plant (T<sub>4</sub>) was able after 65 days to reduce total Acenaphthene, Phenanthrene and Pyrene from 297.8, 21.0 and 251.3 to 51.8, 4.3 and 84.37 mg kg<sup>-1</sup> soil respectively, (i.e. 82.6, 79.5 and 66.3% loss), this is in contrast to 35.9, 37.1 and 29.4 % reduction value for the non-rhizospheric soil (T<sub>3</sub>) in the same 3 PAHs respectively.

**Table (4): Effect of applied treatments on degradation of Acenaphthene, Phenanthrene and Pyrene in soil tested.**

Acenaphthene (mg kg <sup>-1</sup> )						
Treatments	Initial concentration	Soil	Roots	Shoots	Dissipation amount (T)	Dissipation ratio (A %)
T <sub>1</sub> (Control)	297.8 + 4.3	280.1	-	-	17.7	5.9
T <sub>2</sub>		264.3	-	-	33.5	11.2
T <sub>3</sub>		190.8	-	-	107	35.9
T <sub>4</sub>		51.8	31	0.81	246	82.6
Phenanthrene (mg kg <sup>-1</sup> )						
Treatments	Initial concentration	Soil	Roots	Shoots	Dissipation amount (T)	Dissipation ratio (A %)
T <sub>1</sub> (Control)	21 + 1.2	20.2	-	-	0.8	3.8
T <sub>2</sub>		18.1	-	-	2.9	13.8
T <sub>3</sub>		13.2	-	-	7.8	37.1
T <sub>4</sub>		4.3	1.6	0.35	16.7	79.5
Pyrene (mg kg <sup>-1</sup> )						
Treatments	Initial concentration	Soil	Roots	Shoots	Dissipation amount (T)	Dissipation ratio (A %)
T <sub>1</sub> (Control)	251.3 + 14.1	245.1	-	-	6.2	2.5
T <sub>2</sub>		232.6	-	-	18.7	7.4
T <sub>3</sub>		177.3	-	-	74	29.4
T <sub>4</sub>		84.7	18	0.25	166.6	66.3

- Dissipation amount, represent the mean of the three replica.
- Dissipation amount  $T = (C_i - C_e)$
- Dissipation ratio (% A) =  $T \times 100/C_i$
- Where  $C_i$  was the soil initial concentration (mg kg<sup>-1</sup>).
- $C_e$  was the soil residual concentration (mg kg<sup>-1</sup>) after 65 days.

Theses results show the role positive for rhizosphere legume plant Faba bean (T<sub>4</sub>) in enhanced the biodegradation and dissipation of the 3



PAHs individuals tested as compared to the non-rhizosphere soil ( $T_3$ ). This may be due to differences in the nature and composition of root exudates which reflect the biodegradation potential of the microbial community in rhizosphere (Corgie *et al.*, 2004). Dissipation of Acenaphthene, Phenanthrene and Pyrene in planted soil with legume plant (Faba bean) included leaching, a biotic dissipation, biodegradation and plant uptake and accumulation. By contrast, the dissipation of these compounds in unplanted soils was the sum of leaching, a biotic dissipation and biodegradation. Thus the loss of Acenaphthene, Phenanthrene and Pyrene in vegetated and non-vegetated soils could be expressed as

- $T_p = T_l + T_a + T_b + P_a$  ..... (1)
- $T_{unp} = T_l + T_a + T_b$  .....(2)

where  $T_{unp}$  and  $T_p$  were the dissipation of chemicals in spiked unplanted and planted soils ( $mg\ pot^{-1}$ ).  $T_l$  and  $T_a$  denoted the dissipation by leaching and abiotic dissipation respectively.  $T_b$  and  $T_b'$  were the loss by biodegradation in vegetated and non-vegetated soils, respectively.  $P_a$  denoted the removal of chemicals by plant uptake and accumulation. Thus, the dissipation enhancement ( $T_d$ ) of Acenaphthene, Phenanthrene and Pyrene in planted versus unplanted soils was

- $T_d = T_p - T_{unp} = (T_b - T_b') + P_a$  .....(3)
- $T_{pb} = T_b - T_b'$  .....(4)

In Eq.(4)  $T_{pb}$  denoted the loss of Acenaphthene, Phenanthrene and Pyrene by the plant-promoted biodegradation. Obviously, the enhanced dissipation of acenaphthene, phenanthrene and pyrene in planted versus unplanted would strongly derive of plant direct uptake and accumulation and promoted biodegradation.

**Table (5): plant contributions to the remediation enhancement of Acenaphthene, Phenanthrene and Pyrene In planted with Faba bean plants versus unplanted spiked soil with initial concentration of 297.8, 21.0 and 251.3  $mg\ kg^{-1}$  for them respectively after 65 d.**

**	Acenaphthene ( $mg\ kg^{-1}$ )				Phenanthrene ( $mg\ kg^{-1}$ )				Pyrene ( $mg\ kg^{-1}$ )			
	$T_p$	$T_d$	$T_{pb}$	$P_a$	$T_p$	$T_d$	$T_{pb}$	$P_a$	$T_p$	$T_d$	$T_{pb}$	$P_a$
Dissipation amount	246.0	139.0	73.5	31.8	16.7	8.9	4.9	2.0	166.6	92.6	55.3	18.3
Dissipation ratio (%)	82.6	46.7	24.7	10.7	79.5	42.4	23.3	9.3	66.3	36.9	22.0	7.3

- $T_p$  :dissipation amount of Acenaphthene, Phenanthrene and Pyrene in planted soil;
- $T_d$  : dissipation amount enhancement of Acenaphthene, Phenanthrene and Pyrene in planted versus unplanted soil.
- $T_{pb}$  : the loss of Acenaphthene, Phenanthrene and Pyrene in planted soil by plant promoted biodegradation.
- $P_a$ : plant accumulation amount of Acenaphthene, Phenanthrene and Pyrene accumulated in plant planted soil

However, Faba bean direct accumulation of Acenaphthene, Phenanthrene and Pyrene in planted soil was 31.8, 2.0 and 18.3  $mg\ kg^{-1}$ , respectively (i. e. 10.7, 9.3 and 7.3 %) which only accounted for dissipation

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enhancement to 46.7, 42.4 and 36.9 % for acenaphthene, phenanthrene and pyrene in the presence of vegetation. These results agree with the physicochemical properties for these compounds individual.

### **Conclusions**

Phytoremediation can be applied at heavily contamination levels, its preferable to use after the application of other remediation measures as a polishing step to further degrade residual hydrocarbons and improve soil quality. Also, the success of phytoremediation processes is dependant on the plant species to enhance the microbial activity in the plant rhizosphere, particularly with legume plants.

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**استخدام المعالجة النباتية كوسيلة لتحسين الأراضي الملوثة بالمركبات البترولية الهيدروكربونية**  
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المعالجة النباتية للأراضي الملوثة بالمركبات البترولية الهيدروكربونية تبدو تكنولوجيا واعدة لبيئته نظيفه خصوصا في الدول النامية. في هذه الدراسة جمعت عينات من الطبقة السطحية سواء كانت مزروعة او غير مزروعة بقرية كفر العلو مدينة حلوان بمحافظة القاهرة مصر. وذلك من ثلاث اماكن مختلفه حيث كانت الأولى غير ملوثة ( كنترول) والثانيه كانت ملوثة بزيت البترول الخام وغير معاملة. اما الثالثه فكانت ملوثة بزيت البترول الخام وتم زراعتها بعده محاصيل وذلك على التوالي .

أكدت النتائج أن تركيزات العناصر الثقيلة مثل النحاس والزنك والحديد والمنجنيز والكلاديوم والنيكل والرصاص في الطبقة السطحية (صفر - ٣٠ سم) للأراضي الملوثة بزيت البترول الخام قد زادت الى ٤.١ ، ٢.٢ ، ٦.٩ ، ٢.١ ، ٤.٢ ، ٧.٨ ، ٦.١ أضعاف وذلك على التوالي بالمقارنة بتركيزاتها بالأراضي الغير ملوثة. ويعزي ذلك الى أن زيت البترول الخام يكون في الغالب محمل بتركيزات عالية من تلك العناصر. أيضا هذه الزيادة في التركيز كانت تقل مع العمق لانخفاض حركتها.

وقد اظهرت النتائج أيضا أن اعلي فقد في تركيزات العناصر الثقيلة وكذلك المركبات الهيدروكربونية (PAHs) كان في منطقة انتشار الجذور لنبات البرسيم الحجازي ثم القمح والسنرة الرفيعة على التوالي. لذلك فان النبات البقولى (البرسيم الحجازي) ممكن قبوله للقيام بدور المعالجة النباتية للأراضي الملوثة بالمركبات الهيدروكربونية.

على الجانب الأخر فان النتائج تشير الى محدودية انتقال الملوثات العضوية الهيدروكربونية (PAHs) من الجذور الى المجموع الخضري لتلك الأنواع المختلفة من النباتات والمنمات في الأراضي الملوثة. وان التركيزات المتواجدة في المجموع الخضري ربما يكون مصدرها الغلاف الجوى.

كما تبين من نتائج تجربة الأصص ان نمو نبات الفول البلدى في الأراضي الملوثة لمدة ٦٥ يوم يمكن ان يقلل من تركيز كلا من السينافلين والفيانترين والبيرين من ٢٩٧.٨ ، ٢١ ، ٢٥١.٣ الى ٥١.٨ ، ٤.٣ ، ٨٤.٣٧ مليجرام/كجم تربه على التوالي اي بما يعادل ( ٨٢.٦% ، ٧٩.٥% ، ٦٦.٣%) في تلك الأراضي الملوثة.

**قلم بتحكيم البحث**

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