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ORIGINAL ARTICLE

Dissipation of polycyclic aromatic hydrocarbons in crop soils amended with oily sludge

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Abstract Oil fields present a potential ecological risk to nearby farmland soil. Here we present a new method designed to evaluate the ability of winter wheat (*Triticum aestivum*) to contribute to the dissipation of polycyclic aromatic hydrocarbons (PAHs), which are priority pollutants in soils contaminated by oily sludge. The influence of different doses of oily sludge on the dissipation of PAHs was studied along with individual PAH profiles in soils after different periods of plant growth. Five soil samples were artificially contaminated with different percentages of oily sludge (0 %, 5 %, 10 %, 15 % and 20 %). Winter wheat grew in the oily sludge–amended soils for 265 days. PAH content in the soils was monitored over the course of the study. The rate of PAH dissipation is related to the properties of different PAHs, period of winter wheat growth, and oily sludge application dose. Analysis for treated soils indicates that the dissipation of PAHs increased significantly over the first 212 days, followed by minimal changes over the final 53 days of treatment. In contrast, PAH dissipation slowed with increasing oily sludge application. For each PAH, the experimental results showed a significant compound-dependent trend. Winter wheat in the present study significantly enhanced the dissipation of PAHs in oily sludge–contaminated soil.

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1 Introduction

Polycyclic aromatic hydrocarbons (PAHs) are remarkable for their long half-life period in soil and biota. They are by-products from the incomplete combustion or pyrolysis of organic materials and sixteen of them are listed as priority pollutants by the United States Environmental Protection Agency (EPA) (Puglisi et al. 2007; Das et al. 2008; Kim et al. 2013; Zhang et al. 2015). PAHs are concerning mainly for their widespread occurrence, recalcitrance, and toxic/carcinogenic properties which may adversely affect both human health and biota (Yang et al. 2008; Cao et al. 2013; Maria et al. 2014; Wang et al. 2015). PAHs can easily present in soils via atmospheric deposition as well as anthropic activity (such as disposal of waste materials, car tire shredding and road runoff, sewage sludge, industrial wastewater, and compost applied to agricultural land) (Qiao et al. 2008; Edris et al. 2014; Roozbeh et al. 2014; Hu et al. 2015). Soils become the main environmental harbors for these contaminants (Chaineau et al. 2000; Wang et al. 2012, 2013; Tsibart and Gennadiev 2013).

Over the last few years, interest has increased around PAH remediation technologies that are cheap and environmentally friendly (Ortega-Calvo et al. 2007; Peng et al. 2008; Maillacheruvu and Pathan 2009; Minai-Tehrani et al. 2015). Phytoremediation has gained acceptance and now is considered one of the most promising alternative remediation approaches for PAHs in soil (Joner and Leyval 2003; Fernández-Luqueño et al. 2008; Ma et al. 2009; Liu et al. 2013). Much research has been conducted about PAHs in soil and plants (Aichberger et al. 2006; Stroud et al. 2007; Priyanka et al. 2015). However, research focused on PAHs from oily sludges is less abundant (Zhang et al. 2015; Kuang et al. 2008; Nanekar et al. 2015). Little is known about the potential impact of edible plants on the fate of PAHs in oily sludge–contaminated soils and the basic mechanisms involved remain poorly understood (Su and Zhu 2008; Ma et al. 2009; Oleszczuk 2009). On the other hand, increasing oil exploitation continues to produce large amounts of PAH-abundant oily sludge. Improper management of oily sludge causes serious damage to ecosystems and the abundant PAHs in oily sludge may persist in soil for a long time, turning oily sludge disposal into a prominent environmental problem. As PAHs can easily enter sediment, the determination of PAH dissipation in agricultural soil around oilfields is an important research question (Kuang and Chen 2009).

The aim of the present work is to investigate soil PAH dissipation with field phytoremediation. Winter wheat (*Triticum aestivum*) was chosen as the test plant in our research since it is a typical crop in northern China. The experiment was designed to evaluate the ability of winter wheat to contribute to PAH removal. Variation for the dissipation of the sixteen PAHs in the EPA list was determined. In order to simulate environmental conditions, soils used in this experiment were artificially contaminated with different percentages of oily sludge. The results provide the theoretical basis for the proper utilization and scientific management of oily sludge in oil fields.

2 Samples and experiments

2.1 Instruments

PAHs were determined by high performance liquid chromatography (HPLC, Shimadzu, Japan) with a fluorescence detector and VP-ODS column (Serial No. 9122504, 150L × 4.6), and extracted by ultrasonic washer (KQ5200, Kunshan in China). The concentration of PAHs in liquors was finished by rotary evaporator (Shensheng SENCO-R, China) and thermostat water bath (Shensheng W201B, China). PAH samples were separated by low-speed tabletop centrifuge (TDL-40B, Shanghai), Quick mixer (Changzhou, China), and water cycling multipurpose vacuum pump (SHB-III, Zhengzhou in China).

2.2 Reagents

Dichloromethane, cyclohexane, acetonitrile, methanol, silica, and anhydrous sodium sulfate were used. Among them, acetonitrile was chromatographically pure; other reagents were all analytically pure. Methanol was distilled prior to use. Silica was used in the stratographic analysis. PAH standard matters were bought from Supelco Corporation of America.

2.3 Soil samples collection and treatment

Soil used in this experiment was farmland soil without any known contamination history. In order to simulate typical properties of the farmland soil contaminated by oily sludge, winter wheat was cultured in five different soils with increasing mass percentages (0 %, 5 %, 10 %, 15 % and 20 %) of oily sludge. Oily sludge mass percentages were calculated by dry mass. The initial content of each PAH in oily sludge–amended soil was calculated according to the control soil and oily sludge (Yu et al. 2013). The seeds of winter wheat germinated directly in the open air without any fertilization control; water was needed. Due to the long growth cycle of winter wheat, the experiments were carried out for 265 days.

Oily sludge–amended soil samples were collected and analyzed after 53, 106, 159, 212 and 265 days. The soil samples were immediately air-dried, grinded, and sieved after being collected. They were then placed into polyvinyl chloride bags, sealed, and stored at room temperature prior to PAH analyses.

2.4 Extraction, concentration, purification, and determination of PAHs

(1) The extraction, concentration and purification of PAHs. A sample was put into a centrifuge bottle and dichloromethane was added. The centrifuge bottle was kept in the ultrasonic washer for 2 h and then transferred into the centrifugal vacuum pump. A volume of 10.00 mL of supernatant was transferred into an egg yard type bottle, and all the liquids were dried by rotary evaporator. Afterwards, the resulting residue was dissolved with cyclohexane. A 0.50 mL sample of the obtained solution was put on the mini silica column. A second fraction containing PAHs was collected and blown dry with nitrogen.

(2) Determination of PAHs. Samples were determined by HPLC equipped with fluorescence detector. Sample preconcentration liquid and mixed certificated liquid were extracted separately.

The qualitative analysis was done by the comparison of the retention time of PAHs, while the quantitative analysis was carried out by the determination of PAHs using an external standard method. In addition, principal component analysis was conducted with SPSS1 1.0. Categories and contents of PAHs in variously treated soil samples after different periods of plant growth are presented in Tables 1, 2, 3, and

4. (The initial contents of PAHs in the control soil and oily sludge and the contents of PAHs after 265 days of plant growth were illustrated in Yu et al. 2013). The initial contents of individual PAHs in oily sludge–amended soil were calculated according to the content of control soil and oily sludge.

2.5 Data analysis

The dissipation of PAHs was evaluated according to the following formula:

$$\text{PAH dissipation } (\%) = 100 - C_t \times 100 / C_0$$

where C_t is the concentration (μg/g) of PAHs in soil at the time t and C_0 is the concentration (μg/g) of PAHs in soil at the time 0.

3 Results and discussion

Sixteen PAHs listed as priority pollutants presented in study soils. The total PAH contents of oily sludge and control soil were 3504.66 and 16.96 μg/g, respectively. Naphthalene and phenanthrene were predominant in the control soil. In line with the soil, oily sludge used in this experiment had a considerably high content of 2- and 3-ring PAHs. The introduction of sludge into the soil results in an increase in soil PAH content (Baran and Oleszczuk 2003; Oleszczuk and Baran 2005; Varun et al. 2013). Table 5 shows that PAH concentrations in the treated soil varied distinctly during the experimental period. It was found that the apparent losses of PAHs were

Table 1 Residual concentrations (μg/g) of PAHs in treated soil samples after 53 days of plant growth

	Oily sludge mass percentages				
PAH	0 (%)	5 (%)	10 (%)	15 (%)	20 (%)
NaP	8.90	50.01	90.33	131.46	171.97
Any	0.390	23.99	47.61	71.25	94.98
Ane	0.458	29.99	60.11	89.54	119.00
Flu	0.723	33.74	67.21	100.99	134.56
Phe	2.90	22.91	41.69	62.43	82.29
Ant	0.269	2.42	4.55	6.78	8.89
Fla	0.448	1.89	3.28	4.69	6.11
Pyr	0.361	3.51	6.72	9.81	12.94
BaAn	0.422	3.20	5.94	8.67	11.55
Chy	0.196	3.97	7.77	11.60	15.41
Bbf	0.434	1.62	2.80	3.98	5.16
Bkf	0.396	2.21	4.01	5.83	7.64
BaP	0.162	2.50	4.84	7.15	9.48
I1P	0.035	0.711	1.38	2.05	2.72
Daa	0.042	0.517	0.961	1.43	1.89
BgP	0.040	0.694	1.32	1.95	2.59
ΣPAHs	16.18	183.88	350.52	519.61	687.18

Table 2 Residual concentrations (μg/g) of PAHs in treated soil samples after 106 days of plant growth

	Oily sludge mass percentages				
PAH	0 (%)	5 (%)	10 (%)	15 (%)	20 (%)
NaP	8.28	47.21	85.01	120.45	159.88
Any	0.375	23.22	45.53	68.53	90.22
Ane	0.439	28.78	56.00	84.24	111.87
Flu	0.682	32.56	63.09	94.56	126.19
Phe	2.81	21.51	40.23	58.12	79.03
Ant	0.257	2.34	4.39	6.49	8.64
Fla	0.432	1.83	3.17	4.58	5.89
Pyr	0.345	3.41	6.49	9.46	12.69
BaAn	0.404	3.05	5.68	8.21	10.98
Chy	0.185	3.81	7.42	10.97	14.62
Bbf	0.417	1.57	2.71	3.86	4.98
Bkf	0.381	2.14	3.89	5.63	7.37
BaP	0.156	2.42	4.70	6.97	9.19
I1P	0.035	0.696	1.34	2.01	2.71
Daa	0.041	0.482	0.913	1.34	1.76
BgP	0.040	0.671	1.30	1.92	2.58
ΣPAHs	15.28	175.70	331.86	487.34	648.60

Table 3 Residual concentrations (μg/g) of PAHs in treated soil samples after 159 days of plant growth

	Oily sludge mass percentages				
PAH	0 (%)	5 (%)	10 (%)	15 (%)	20 (%)
NaP	6.51	35.75	67.18	96.02	123.19
Any	0.309	18.80	37.12	54.98	73.55
Ane	0.345	23.08	45.99	67.73	89.04
Flu	0.536	25.71	51.47	75.01	100.39
Phe	2.34	17.96	32.64	47.58	63.83
Ant	0.217	1.98	3.62	5.47	7.11
Fla	0.357	1.49	2.65	3.71	4.88
Pyr	0.289	2.88	5.58	7.93	10.52
BaAn	0.342	2.56	4.72	6.86	9.32
Chy	0.159	3.23	6.27	9.14	12.56
Bbf	0.349	1.31	2.31	3.18	4.21
Bkf	0.319	1.79	3.23	4.67	6.20
BaP	0.135	2.09	4.03	6.02	7.91
I1P	0.034	0.665	1.28	1.91	2.54
Daa	0.035	0.421	0.821	1.17	1.58
BgP	0.039	0.651	1.27	1.88	2.49
ΣPAHs	12.32	140.37	270.18	393.26	519.32

Table 4 Residual concentrations (μg/g) of PAHs in treated soil samples after 212 days of plant growth

Oily sludge mass percentages					
PAH	0 (%)	5 (%)	10 (%)	15 (%)	20 (%)
NaP	2.66	17.65	33.39	51.31	75.83
Any	0.137	8.57	20.77	31.54	45.13
Ane	0.141	10.08	23.23	37.68	54.14
Flu	0.233	12.63	25.09	42.55	61.91
Phe	0.977	8.10	17.45	27.42	38.01
Ant	0.094	0.897	1.87	3.13	4.32
Fla	0.158	0.752	1.35	2.18	3.00
Pyr	0.142	1.58	2.99	4.82	6.92
BaAn	0.141	1.24	2.42	3.79	5.47
Chy	0.066	1.49	3.08	4.99	7.28
Bbf	0.162	0.674	1.27	1.89	2.56
Bkf	0.147	0.932	1.81	2.78	3.83
BaP	0.068	1.15	2.40	3.76	5.31
I1P	0.019	0.391	0.812	1.22	1.73
Daa	0.019	0.257	0.521	0.820	1.14
BgP	0.029	0.513	1.00	1.50	1.99
ΣPAHs	5.19	66.89	139.46	221.37	318.58

PAHs: NaP naphthalene, Any acenaphthylene, Ane acenaphthene, Flu fluorene, Phe phenanthrene, Ant anthracene, Fla fluoranthene, Pyr pyrene, BaAn benzo(a)anthracene, Chy chrysene, Bbf benzo[b]fluoranthene, Bkf benzo[k]fluorantene, BaP benzo[a]pyrene, I1P indeno(1, 2, 3-cd)pyrene, Daa dibenzo(a, h)anthracene, BgP benzo(g,h,i)perylene

related to the properties of different PAHs, the period of winter wheat growth, and oily sludge application dose.

3.1 Impact of time on PAH dissipation

The period of winter wheat growth was an important factor affecting PAH losses. During the whole period of study, continuous variation of PAH content was observed. The dissipation rate of PAHs increased significantly with time. For example, the average dissipation rate (for all studied soils) of predominant PAHs in the period of the first 53 days was only 4.94 %, 3.43 %, 3.79 %, 3.63 % and 3.86 % for naphthalene, acenaphthylene, acenaphthene, fluorene, and phenanthrene, respectively, while in the continuous period of the first 212 days the corresponding losses of those PAHs were 64.78 %, 60.17 %, 63.32 %, 62.37 %, and 61.33 %, followed by minimal variations over the subsequent 53 days of treatment. The applied dissipation rates of PAHs explain the variability of the low values in the initial period of the first 53 days; the dissipation rates increased with time to the largest value of 70.67 % at the end of the experiment. Figure 1 presents the significant trend of total PAH content in treated soils related to the days of winter wheat growth. The most pronounced dissipation of PAHs was found at the heading stage of winter wheat.

The dissipation rates of individual PAHs are illustrated in Table 5; the half-lives for most PAHs (5- and 6-ring PAHs being the exception) were between 59 and 212 days irrespective of oily sludge application dose. For example, the $T_{1/2}$ values for most PAHs in soil contaminated by oily sludge at 20 % approached 212 days. As for 5- and 6-ring PAHs (benzo[a]pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene), the half-lives were not reached by the end of the study. The highest $T_{1/2}$ values corresponded to naphthalene and the lowest to benzo(g,h,i)perylene.

3.2 Effect of PAHs properties on PAHs dissipation

As for individual PAHs, the overall extent of PAH loss from all treated soils showed a significant compound-dependent trend in line with previous findings (Fismes et al. 2002; Gao and Zhu 2004; Ian et al. 2013; Jin et al. 2014). The average concentration of PAHs with various rings in soil samples are listed in Fig. 2, which shows that the properties of PAHs strongly influence the extent of their dissipation. The dissipation rates of low-molecular-weight PAHs are much higher than those of high-molecular-weight PAHs, despite the fact that low-molecular-weight PAHs are predominant in soil. In the experimental treatment with various doses of oily sludge, more than half (51.66 %) of 2- to 4-ring PAHs degraded, whereas the dissipation was much lower in the case of 5- to 6-ring PAHs. For example, the lowest dissipation in the present study was only 27.94 %. This pronounced trend is in agreement with many other research reports, which suggests that high-molecular-weight PAHs are more resistant to microbial attack than low-molecular-weight PAHs (Tabak et al. 2003; Lee et al. 2008).

3.3 Impact of oily sludge application on PAH dissipation

The contents of PAHs in treated soils increase along with the oily sludge percentages. The dissipation rate of PAHs in soils planted with winter wheat was negatively correlated with the percentages of oily sludge. The reduction of PAH dissipation ratios might be attributed to the more negative effect of PAHs on winter wheat growth with the percentages of oily sludge increasing. The cause might be the inherent toxicity of PAHs; PAHs might have indirect adverse effects on plants by reducing the ability of soil to provide nutrients and water for plants.

The removal extent for individual PAHs depended on the oily sludge dose. For example, the dissipation rates for naphthalene and phenanthrene after 265 days of plant

Table 5 The rates of PAH dissipation in different soils after different periods of plant growth

Oily sludge mass percentages															
PAH	159 days					212 days					265 days				
	0 (%)	5 (%)	10 (%)	15 (%)	20 (%)	0 (%)	5 (%)	10 (%)	15 (%)	20 (%)	0 (%)	5 (%)	10 (%)	15 (%)	20 (%)
NaP	30.56	31.68	29.50	30.55	32.02	71.63	66.28	64.96	62.89	58.16	76.64	69.83	67.46	64.44	59.97
Any	23.51	24.38	24.74	25.47	25.12	66.09	65.54	57.90	57.24	54.06	70.05	67.83	61.28	61.77	57.55
Ane	27.52	26.31	26.01	27.17	28.10	70.38	67.82	62.62	59.48	56.28	72.90	70.61	66.29	62.26	59.24
Flu	28.44	27.17	26.32	28.16	27.76	68.89	64.21	64.08	59.24	55.45	73.83	70.67	65.18	62.55	58.65
Phe	23.57	23.64	25.77	26.15	24.80	68.10	65.56	60.32	57.45	55.21	73.62	67.98	65.42	61.33	58.16
Ant	22.22	21.82	24.11	22.08	23.30	66.31	64.54	60.76	55.45	53.41	72.40	68.38	63.77	60.43	58.17
Fla	23.06	22.80	21.83	23.51	22.66	65.95	61.04	60.26	55.14	52.47	70.69	65.91	62.92	60.30	55.15
Pyr	21.47	20.66	19.01	21.87	21.55	61.41	56.53	56.56	52.52	48.37	64.13	60.46	59.44	55.86	51.66
BaAn	22.27	23.12	23.99	24.62	22.20	67.95	62.77	61.01	58.31	54.34	71.14	67.38	63.48	59.69	57.63
Chy	21.67	21.98	22.30	23.90	21.25	67.49	64.02	61.79	58.44	54.37	71.92	67.46	63.46	60.31	57.44
Bbf	21.75	21.56	20.07	22.63	21.01	63.68	59.61	56.05	54.08	52.02	67.94	63.49	61.07	57.08	53.83
Bkf	21.62	21.49	22.17	22.55	21.52	63.88	59.13	56.39	53.96	51.48	66.34	63.71	59.86	57.38	54.12
BaP	18.18	18.68	19.08	18.43	19.20	58.79	55.45	51.87	49.05	45.72	61.21	57.67	54.40	50.91	48.27
I1P	5.56	8.90	9.86	9.48	9.29	47.22	46.46	42.85	41.98	38.18	52.78	47.50	44.17	43.11	39.90
Daa	20.45	20.57	18.71	21.48	19.80	56.82	51.44	48.38	44.99	42.02	63.64	57.18	55.51	53.17	47.28
BgP	4.88	7.00	5.93	6.47	6.39	29.27	26.73	25.87	25.42	25.08	34.15	31.07	27.94	28.33	28.70

PAHs: NaP naphthalene, Any acenaphthylene, Ane acenaphthene, Flu fluorene, Phe phenanthrene, Ant anthracene, Fla fluoranthene, Pyr pyrene, BaAn benzo(a)anthracene, Chy chrysene, Bbf benzo[b]fluoranthene, Bkf benzo[k]fluoranthene, BaP benzo[a]pyrene, I1P indeno(1, 2,3-cd)pyrene, Daa dibenzo(a, h)anthracene, BgP benzo(g,h,i)perylene

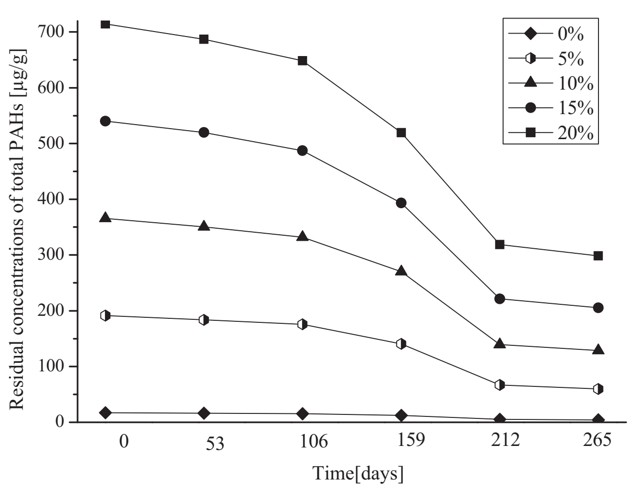

Fig. 1 Total PAH content in treated soils with respect to the days of winter wheat growth

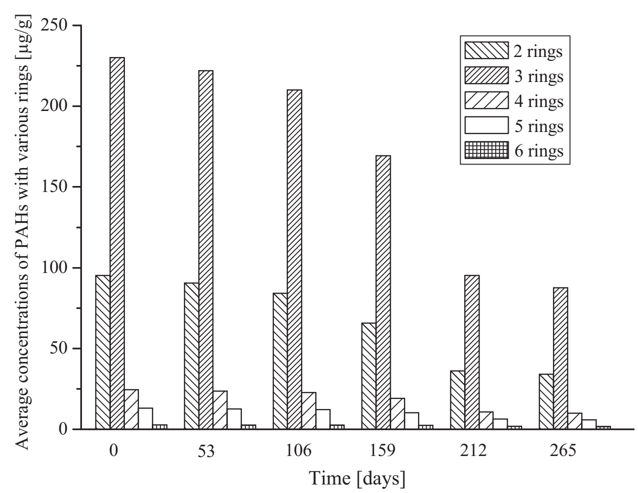

Fig. 2 The average concentrations (μg/g) of PAHs (for all studied soils) with various rings in treated soils

growth were 59.97 % and 58.16 %, respectively, in planted soil with a 20 % oily sludge dose, which were significantly lower than in soil with a 5 % oily sludge dose 5 %–69.83 % and 67.98 %, respectively. Figure 3 presents the pronounced trend of total PAH content in planted soil with respect to the oily sludge percentages.

3.4 Enhancement of PAH dissipation in crop soil

The residual concentrations of PAHs in control soil with and without winter wheat planted were analyzed. The residual concentrations of PAHs in the planted soil without oily sludge application were lower than those in

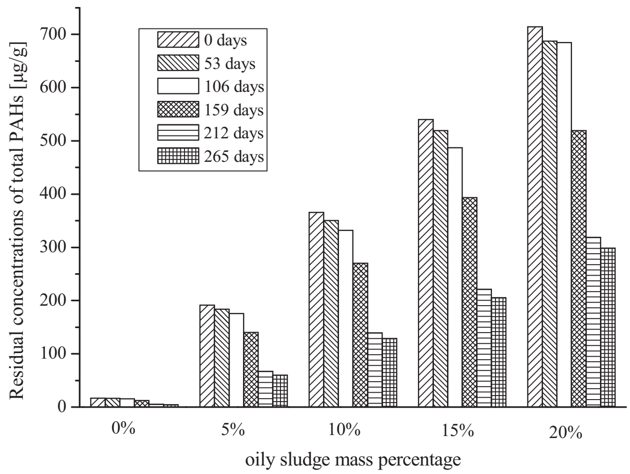

Fig. 3 Total PAH content in planted soils with respect to oily sludge dose (defined as the ration of oily sludge weight and soil total weight on a dry weight basis)

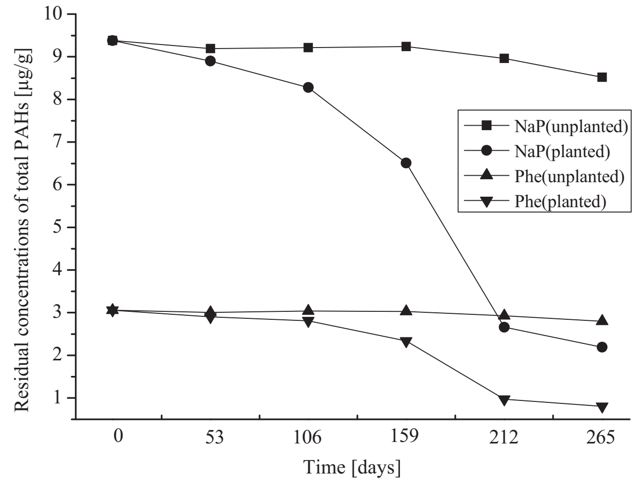

Fig. 4 Residual concentrations of NaP and Phe in planted and unplanted soils with respect to the period of winter wheat growth

corresponding unplanted soil. Residual concentrations (μg/g) of PAHs in the control soil samples after different periods of monitoring are illustrated in Table 6. Naphthalene and phenanthrene were predominant in the control soil. For example, the dissipation rates of naphthalene and phenanthrene in planted soil with initial concentrations of 9.375 and 3.063 μg/g were 71.63 % and 68.10 % after 212 days of plant growth. These rates are significantly higher compared with corresponding rates in unplanted soil—4.45 % and 4.38 %, respectively. Pronounced increases in dissipation of naphthalene and phenanthrene in planted and unplanted soils after different periods of plant growth are illustrated in Fig. 4.

Table 6 Residual concentrations of PAHs (μg/g) in the control soil samples after different periods

PAH/days	0	53	106	159	212	265
NaP	9.38	9.19	9.21	9.24	8.96	8.52
Any	0.404	0.399	0.402	0.401	0.387	0.368
Ane	0.476	0.472	0.475	0.474	0.455	0.433
Flu	0.749	0.741	0.746	0.743	0.718	0.684
Phe	3.06	3.01	3.04	3.03	2.93	2.80
Ant	0.279	0.277	0.277	0.276	0.268	0.256
Fla	0.464	0.460	0.461	0.459	0.445	0.426
Pyr	0.368	0.366	0.364	0.361	0.354	0.339
BaAn	0.440	0.435	0.434	0.430	0.424	0.406
Chy	0.203	0.201	0.201	0.199	0.196	0.188
Bbf	0.446	0.441	0.440	0.438	0.431	0.414
Bkf	0.407	0.403	0.403	0.401	0.393	0.378
BaP	0.165	0.164	0.164	0.162	0.160	0.155
I1P	0.036	0.036	0.035	0.035	0.035	0.034
Daa	0.044	0.043	0.043	0.043	0.043	0.042
BgP	0.042	0.041	0.041	0.041	0.041	0.040
ΣPAHs	16.96	16.68	16.74	16.73	16.24	15.48

PAHs: NaP naphthalene, Any acenaphthylene, Ane acenaphthene, Flu fluorene, Phe phenanthrene, Ant anthracene, Fla fluoranthene, Pyr pyrene, BaAn benzo(a)anthracene, Chy chrysene, Bbf benzo[b]fluoranthene, Bkf benzo[k]fluoranthene, BaP benzo[a]pyrene, I1P indeno(1, 2, 3-cd)pyrene, Daa dibenzo (a, h) anthracene, BgP benzo(g,h,i)perylene

Winter wheat evidently promotes the dissipation of PAHs. The observed results, based on the dissipation ratios of PAHs in planted and unplanted soil, confirm the impact of winter wheat. After 265 days, PAH contents significantly decreased in the planted soils, corroborating many other studies. The reasons for the loss of PAHs from soil might be plant uptake, bio-transformation, bio-degradation, or abiotic dissipation, including leaching and volatilization (Shaw and Burns 2003; Kunihiro et al. 2013; Li et al. 2015). However, many researchers have reported that plant direct accumulation of PAHs only accounted for a slight share of the enhanced dissipation and could be assumed to be negligible (Ke et al. 2003; Xu et al. 2005). The dominant contribution to the loss of PAHs might be plant-promoted biodegradation. The enhanced dissipation of PAHs might be rooted in greater activity of microorganisms and a higher density in planted soil. The plant litter and root exudates could modify the soil environment more suitably for microbial transformation, enhancing the bioavailability of the contaminants and providing substrates for co-metabolic dissipation (Ke et al. 2003).

4 Conclusions

The present study reveals the potential ecological risk of the farmland soil around oil fields. The rates of PAH dissipation in crop soil contaminated with PAHs are related to

PAH properties and concentrations. The persistence of PAHs is also significantly influenced by winter wheat growth. Prolonged winter wheat growth leads to a decrease in PAH dissipation rates. The influence was important in the period from 159 to 212 days with only a minor reduction over the subsequent 53 days of treatment. In this the period from 159 to 212 days, the specific properties of PAHs had a very slight effect on the loss of PAHs. The residual concentrations of PAHs in planted and unplanted soils indicate that the presence of winter wheat significantly enhanced the dissipation of PAHs, regardless of the variation in initial concentrations of PAHs in the control soil.

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