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The application of composting materials to degrade polycyclic aromatic hydrocarbon on oil field drill cuttings

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The potential effects of using poultry droppings and mushroom substrate, either alone or in combination, as amendments or nutrient supplements for hydrocarbon biodegradation were investigated in this study. The rates of biodegradation of drill cuttings were studied over remediation periods of 4 and 8 weeks under laboratory conditions. The concentrations of polycyclic aromatic hydrocarbons (PAHs) in untreated drill cuttings, spent mushroom substrate, and poultry manure were 18.464, 13.29, and 19.59 mg kg^{-1}, respectively. The first-order empirical model was employed to predict changes in hydrocarbon concentrations. Subsequently, Biodegradation Efficiency (BDE), Diagnostic Ratio, and Toxicity Equivalent Factor (TEF) were determined. Analysis of the empirical data revealed a highly statistically significant difference in PAHs at 8 weeks due to the amendment. Notably, spent mushroom substrate (SMS) exhibited better performance on its own compared to animal waste (poultry droppings). However, a combination of poultry droppings and SMS (4:1:1) resulted in higher values of BDE. Diagnostic ratios calculated indicated that PAHs originated from both combustion and anthropogenic sources. TEF demonstrated a reduction in value from 4 to 8 weeks, with the 14 individual PAHs investigated showing a 50% reduction in fluoranthene. Conversely, the biodegradation rate constants obtained were higher with lower half-life times for the various amendments using plant and animal-source organic wastes, either alone or in combinations.

Key words: Toxicity equivalent factor (TEF), biodegradation efficiency (BDE), diagnostic ratio, polycyclic aromatic hydrocarbons (PAHs), drill cuttings, poultry droppings, spent mushroom substrate.

INTRODUCTION

A substantial volume of oily sludge is generated during oil production and processing activities, with oil and gas drilling operations worldwide producing drill-cutting wastes. Managing fossil fuel waste has become a prominent topic in the environmental industry in recent years. Historically, these drill cuttings were often disposed of in water bodies or on land without any prior treatment (Browning and Seaton, 2005). Additionally, companies

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engaged in burning fossil fuels commonly stockpiled waste, either relocating it or burying the drill cuttings, thereby exacerbating contamination risks.

Most fossil fuel waste, specifically drill cuttings, contains a considerable amount of polycyclic aromatic hydrocarbons (PAHs), which serve as a potent energy source for mycelium (spent mushroom compost). Drill cuttings have been characterized by a relatively high content of PAHs (DPR, 2002) and heavy metals (Khajiagbe et al., 2014). Over the years, various methods, including thermal treatment technologies, solidification/stabilization (Shaffer et al., 1998; Allagoa, 2014), and mechanochemistry (Peng et al., 2018), have been employed for the management of drill cuttings.

Since the 1970s, biological treatments have been actively utilized for hydrocarbon degradation and are now considered among the most effective cleanup alternatives for soil (Kuppusamy et al., 2017). Composting, as an *ex-situ* bioremediation technology, is particularly adept at treating large volumes of polluted soils. It plays a crucial role in the sustainable recycling of organic waste (Fermor, 1993; Tuomela et al., 2000; Andrew et al., 1999; Hachicha et al., 2009; Greenway and Song, 2002) and results in a marketable end product used as a soil conditioner and organic fertilizer.

The addition of organic waste is essential to promote the development of a diverse microbial community capable of breaking down complex contaminants (Aitken et al., 1992; Jorgensen et al., 2000; Ma et al., 2016). A case study on Mushroom compost-assisted remediation of soil contaminated with PAHs from a manufactured gas plant was conducted in a thermally insulated composting chamber. The degradation of individual PAHs ranged from 20.6% at the end of 54 days of composting, with a subsequent increase in PAH removal to 37-80% after 100 days of maturation (Malachova et al., 2003).

Paladino et al. (2016) conducted a study on the bioremediation of drilling wastes contaminated with heavy hydrocarbons through composting. Following the experiment, a substantial degradation of total hydrocarbons (approximately 82%) and the 16 USEPA-listed PAHs (approximately 93%) was observed.

Kinetic models, known for predicting residual contaminant concentrations, have proven useful in previous studies (Venosa and Holder, 2007; Bayen et al., 2009).

In the present study, compost experiments were conducted on drill cuttings, and subsequently, we calculated the first-order empirical model to predict changes in hydrocarbon concentrations. Finally, we determined Biodegradation Efficiency (BDE), diagnostic ratios, and the toxicity equivalent factor (TEF).

MATERIALS AND METHODS

Study area description

Rivers State produces a significant portion of Nigeria's crude oil. The city is situated within the tropical rainforest zone, experiencing a mean annual rainfall of approximately 2400 mm, a monthly relative humidity of 85%, and mean daily minimum and maximum temperatures of about 25 and 31.5°C, respectively. Table 1 shows the experimental layout.

Laboratory analysis

The samples were air-dried and weighed. A ratio of 1:2 was maintained between the samples and the solvent. Analytical grade hexane and dichloromethane were used in the required quantities for extraction when needed. The dry/cold extraction method was employed for sample separation. Following extraction, the resulting extract was prepared for gas chromatography analysis.

The diagnostic ratios on PAHs to determine their sources

PAH ratios determine PAH sources, clarify samples by locations, and estimate (Yunker et al., 2002). Table 2 shows the diagnostic ratios used in this study with their typical values for particular processes.

Benzo[a]Pyrene equivalent (B[a]Peq) estimation

BaP equivalent concentration (BaPeq) evaluated the toxicities of PAHs in sampling sites. Therefore, the total PAH concentration is expressed as B[a]Peq to illustrate the toxic potency (Igbiri et al., 2017). As proposed earlier by Nisbet and Lagoy (1992) and Igbiri et al. (2017), the B[a]Peq is the summation of the B[a]Peqi. It is the value for specific PAHs or individual PAH concentrations in the sample (cPAHi) multiplied by its toxic equivalency factor (TEFPAHi). Table 3 shows the toxicity equivalent factor value of the individual PAHs.

$$B[a]Peq = \sum(BaPeqi) = \sum(cPAHi \times TEFPAHi) \text{ or } \sum BaPeq = \sum Ci \times TEFi \quad (1)$$

where Ci is the concentration of individual PAHs and TEFi is the corresponding toxic equivalency factor.

Quantification and characterization of degradation

The biodegradation rates of PAHs were evaluated by comparing the reaction rate constants of the pseudo-first-order kinetics as described by Okparanma et al. (2011) and expressed as:

$$\boldsymbol{Log\ Co - Ct = Log\ Co - \left(\frac{K1}{2.303}\right) \times t} \quad (2)$$

Make K_1 the subject formula from Okparanma et al. *(*2011).

$$\boldsymbol{K1 = \frac{2.303}{t} \times [(Log\ Co) - (Log\ Co - Ct)]} \quad (3)$$

where K is the apparent constant reaction rate of the pseudo-first-order (1/week) and t is the time (weeks).

Then, the half-life of the respective PAHs:

$$T_{1/2} = 0.693 / K_1 \quad (3)$$

Biodegradation efficiency (BDE):

$$\boldsymbol{BDE(\%) = \frac{Co - Ct}{Co} \times 100} \quad (4)$$

Table 1. Experimental layout.

Reactor	Compost
Control	Untreated drill-cuttings
Reactor 1	Drill cuttings + top soil + (PD+SD) that is, 4:1:1; 2000 g + 500 g + 500 g
Reactor 2	Drill cuttings + top soil + SMS that is, 4:1:1; 2000 g + 500 g + 500 g
Reactor 3	Drill cuttings + top soil + (PD+SD) that is, 4:1:2; 2000 g + 500 g + 1000 g
Reactor 4	Drill cuttings + top soil + SMS that is, 4:1:2; 2000 g + 500 g + 1000 g
Reactor 5	Drill cuttings + top soil + (PD+SD) that is, 4:1:4; 2000 g + 500 g + 2000 g
Reactor 6	Drill cuttings + top soil + SMS that is, 4:1:4; 2000 g + 500 g + 2000 g
Reactor 7	Drill cuttings + top soil + (PD+SD) + SMS that is, 4:1:1; 2000 g + 500 g + 500 g

PD - Poultry droppings, SD - saw dust, SMS - spent mushroom substrate.

Table 2. Diagnostic ratios used in this study with their typical values for particular processes.

PAHs ratio	Values	Source	References
∑LMW/∑HMW	<1 >1	Pyrogenic/Anthropogenic Petrogenic/Natural	Zhang et al. (2008)
Ant/(ant + Phe)	<0.1 >0.1	Petrogenic/Natural Pyrogenic/Anthropogenic	Pies et al. (2008)
BaA/(BaA + CHR)	<0.2 0.35	Petrogenic/Natural Combustion	Yunker et al. (2002)

Table 3. Toxicity equivalent factor value of the individual PAHs.

PAHs	Toxicity equivalent factor	Reference
Naphthalene	0.001	Nisbet and Lagoy (1992)
Phenanthrene	0.001	
Anthracene	0.01	
Acenaphthelene	0.001	
Acenaphthylene	0.001	
Flourene	0.001	
Pyrene	0.001	
Chrysene	0.01	
Benzo[a]anthracene	0.1	
Fluoranthane	0.001	

where C_o is the initial concentration and C_t is the final concentration.

Statistical analysis

The data were presented as the mean of triplicates (n=3) ± standard error. ANOVA or general linear model (GLM) tests and t-test in MINITAB 16.0 were identified as $p \leq 0.05$.

RESULTS AND DISCUSSION

The mean concentrations of PAHs in the drill cuttings with amended plant residues and animals, either alone or in combination, are presented in Table 4. It was observed that the percentage reduction of PAHs was rapid at 8 weeks in the amended wastes. By the end of 8 weeks, the ∑PAHs reduction in the seven reactors is as follows: 31.85, 53.77, 44.83, 62.32, 59.27, 58.96, and 52.87%. At the conclusion of the remediation period (8 weeks), reactor 2 with SMS (4:1:2) exhibited the highest reduction in PAHs concentration (65.06%) (Figure 1). This was followed relatively by reactor 4 (56.82%), reactor 6 (53.62%), reactor 4 (50.24%), reactor 5 (48.32%), reactor 3 (45.93%), and reactor 1 (28.55%).

Adesodun and Mbagwu (2008) confirmed in their study that poultry droppings performed better at high oil

Table 4. 14PAHs concentration on the seven reactors for 4 and 8 weeks.

PAHs	PD + SD (4:1:1)		SMS (4:1:1)		PD + SD (4:1:2)		SMS (4:1:2)		PD +SD (4:1:4)		SMS (4:1:4)		(PD+SD) + SMS (4:1:1)	
	4weeks	8weeks	4weeks	8weeks	4weeks	8weeks	4weeks	8weeks	4weeks	8weeks	4weeks	8weeks	4weeks	8weeks
1	49.8	44.0	2.1	1.3	31.7	22.0	11.3	3.3	8.0	2.4	5.1	1.3	4.0	1.1
2	39.9	30.0	3.2	1.3	11.9	7.4	12.9	2.4	24.8	7.6	3.5	2.4	16.2	9.6
3	753.9	545.9	173.4	70.5	337.5	92.2	176.3	51.6	162.1	38.4	76.6	31.6	154.7	59.0
4	814.8	617.2	445.9	356.3	725.2	565.9	356.2	139.6	286.7	58.9	154.9	32.2	263.0	137.5
5	2457.6	2110.8	2064.6	673.9	743.2	605.7	956.9	429.3	515.6	296.3	210.6	157.2	505.3	301.5
6	2157.2	1856.2	1051.0	228.5	1679.1	1072.1	1248.7	663.2	305.2	147.6	455.3	256.8	1128.7	577.7
7	2464.0	1924.3	1936.1	1219.3	2224.7	1103.6	875.7	158.2	634.4	229.9	537.3	339.7	917.2	839.6
8	1134.9	1009.1	405.0	300.6	1031.1	451.0	1030.8	747.6	433.7	289.8	143.5	39.2	1034.2	447.9
9	1300.1	182.5	871.3	217.0	1477.3	850.0	1075.0	667.6	513.0	262.8	158.3	36.6	595.7	340.2
10	238.8	191.0	80.5	50.9	1128.5	47.1	468.7	227.7	271.9	25.2	64.9	19.8	346.0	227.7
11	127.2	64.9	615.1	57.6	404.3	100.5	188.2	47.7	250.9	94.5	444.5	225.3	453.7	50.7
12	66.5	47.3	157.1	132.6	183.3	103.8	215.7	52.3	162.2	111.1	132.8	31.4	240.6	25.0
13	218.8	99.4	521.9	195.8	660.7	516.3	769.6	192.3	659.9	118.7	463.9	80.3	135.1	61.4
14	924.1	385.4	2868.4	406.5	1008.2	759.3	3511.3	1321.7	1884.9	1358.8	1415.3	724.9	1749.0	819.7
Total	12747.4	9108.0	11195.5	3912.0	11646.5	6296.8	10897.2	4704.5	6113.0	3041.7	4266.4	1978.7	7543.2	3898.6

1- Naphthalene, 2- Acenaphthylene, 3- Acenaphthelene, 4- Flourene, 5- Phenanthrene, 6- Anthracene, 7- Fluoranthene, 8- Benzo[a]anthracene, 9- Chrysene, 10- Benzo[b]Fluoranthene, 11- Benzo[a]pyrene, 12- Indeno [1,2,3-cd]pyrene, 13- Dibenzo[a,h]anthracene, 14- Indeno[1,2,3-cd]pyrene.

pollution levels, while Phan and Sabaratnam (2012) showed that spent mushroom substrate was more effective at both low and high oil pollution levels. According to Juhasz and Naidu (2000), many bacteria rapidly transform low molecular weight PAHs. Shuttleworth and Cerniglia (1995), as well as Kanaly and Harayama (2000), confirmed that high molecular weight PAHs are more recalcitrant in the environment and may resist both chemical and microbial degradation. Analyzing the data from Table 5 on reactors 2, 4, and 6, it was observed that Acenaphthene (62.95%) degraded better than all the other 3-ringed compounds. Chrysene (63.28%) demonstrated superior degradation as compared to all 4-ringed compounds, while Dibenzo[a.h]anthracene (73.39%) degraded better than all the 5-ringed compounds investigated in this study. Boyle et al. (1992) and Song (1999) found greater disappearance rates after inoculating their samples with white rot fungi. During this investigation, Spent Mushroom Substrate (SMS) demonstrated the ability to degrade a significant amount of 3, 4, 5, and 6-ringed PAHs, highlighting its potential for PAH degradation. Analyzing the data from the table for reactors 1, 3, and 5, it was observed that Acenaphthene (58.87%) degraded more effectively than all the other 3-ringed compounds. Chrysene (59.06%) demonstrated superior degradation compared to all 4-ringed compounds, while Benzo[b]Fluoranthane (68.85%) degraded better than all the 5-ringed compounds investigated in this study. Poultry droppings were reported to enhance the degradation of hydrocarbons in soil compost mixtures (Agarry et al., 2010). The increase in microbial population and rapid degradation of some of the PAHs continued with an increase in amendments to the drill cuttings with poultry droppings. In Table 5, a 31.85 to 59.27% reduction was observed after additional amendment at 8 weeks. Analyzing the data from Table 5, reactor 7 was observed to have Acenaphthene (61.8%) degraded more effectively than all the other 3-ringed compounds. Benzo[a]anthracene (56.7%) demonstrated superior degradation compared to all 4-ringed compounds, while Benzo[a]pyrene (88.8%) and Indeno[1,2,3-cd] pyrene (89.6%) degraded better than all the 5-ringed compounds investigated. Since poultry manure is rich in carbon and mineral

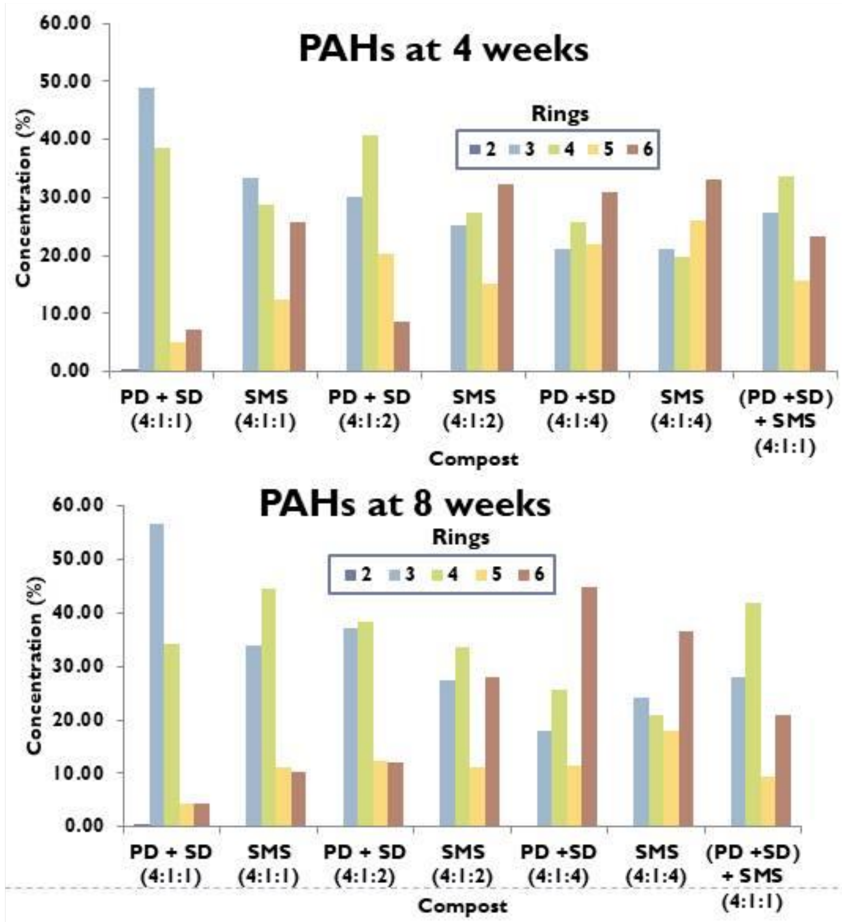

Figure 1. PAHs at 4 and 8 weeks.

Table 5. BDE (%) of the individual PAHs investigated.

PAHs	BDE (%)						
	PD + SD (4:1:1)	SMS (4:1:1)	PD + SD (4:1:2)	SMS (4:1:2)	PD +SD (4:1:4)	SMS (4:1:4)	(PD+SD) + SMS (4:1:1)
1	11.6	39.7	30.6	71.0	70.1	74.5	72.4
2	24.7	58.8	37.8	81.3	69.4	31.2	40.7
3	27.6	59.3	72.7	70.7	76.3	58.8	61.8
4	24.3	20.1	22.0	60.8	79.5	79.2	47.7
5	14.1	67.4	18.5	55.1	42.5	25.4	40.3
6	14.0	78.3	36.1	46.9	51.6	43.6	48.8
7	21.9	37.0	50.4	81.9	63.8	36.8	8.5
8	11.1	25.8	56.3	27.5	33.2	72.6	56.7
9	86.0	75.1	42.5	37.9	48.8	76.9	42.9
10	20.0	36.8	95.8	51.4	90.7	69.5	34.2
11	48.9	90.6	75.1	74.6	62.3	49.3	88.8
12	28.8	15.6	43.4	75.8	31.5	76.3	89.6
13	54.6	62.5	21.9	75.0	82.0	82.7	54.6
14	58.3	85.8	24.7	62.4	27.9	48.8	53.1

1- Naphthalene, 2- Acenaphthylene, 3- Acenaphthelene, 4-Flourene, 5- Phenanthrene, 6- Anthracene, 7- Fluoranthene, 8-Benzo[a]anthracene, 9-Chrysene, 10-Benzo[b]Fluoranthene, 11-Benzo[a]pyrene, 12- Indeno[1,2,3-cd]pyrene, 13-Dibenzo[a,h]anthracene, 14- Indeno[1,2,3-cd]pyrene.

Table 6. Three Diagnosti ratio calculated for 4 and 8 weeks.

Compost	4 weeks			8 weeks		
	∑LMW/∑HMW	Ant/(ant + Phe)	BaA/(BaA + CHR)	∑LMW/∑HMW	Ant/(ant + Phe)	BaA/(BaA + CHR)
PD + SD (4:1:1)	1.0	0.5	0.5	1.3	0.5	0.8
SMS (4:1:1)	0.5	0.3	0.3	0.5	0.3	0.6
PD + SD (4:1:2)	0.4	0.7	0.4	0.6	0.6	0.3
SMS (4:1:2)	0.3	0.6	0.5	0.4	0.6	0.5
PD +SD (4:1:4)	0.3	0.4	0.5	0.2	0.3	0.5
SMS (4:1:4)	0.3	0.7	0.5	0.3	0.6	0.5
(PD +SD) + SMS (4:1:1)	0.4	0.7	0.6	0.4	0.7	0.6

Table 7. The TEF of the seven reactors in 4 and 8 weeks for the 10PAHs.

PAHs	PD + SD (4:1:1)		SMS (4:1:1)		PD + SD (4:1:2)		SMS (4:1:2)		PD +SD (4:1:4)		SMS (4:1:4)		(PD+SD) + SMS (4:1:1)	
	4 weeks	8 weeks	4 weeks	8 weeks	4 weeks	8 weeks	4 weeks	8 weeks	4 weeks	8 weeks	4 weeks	8 weeks	4 weeks	8 weeks
1	0.05	0.04	0.002	0.001	0.03	0.02	0.01	0.003	0.01	0.002	0.005	0.001	0.004	0.001
2	2.46	2.11	2.065	0.674	0.74	0.61	0.96	0.429	0.52	0.296	0.211	0.157	0.505	0.302
3	21.57	18.56	10.510	2.285	16.79	10.72	12.49	6.632	3.05	1.476	4.553	2.568	11.287	5.777
4	0.75	0.55	0.173	0.071	0.34	0.09	0.18	0.052	0.16	0.038	0.077	0.032	0.155	0.059
5	0.04	0.03	0.003	0.001	0.01	0.01	0.01	0.002	0.02	0.008	0.004	0.002	0.016	0.010
6	0.81	0.62	0.446	0.356	0.73	0.57	0.36	0.140	0.29	0.059	0.155	0.032	0.263	0.138
7	13.00	1.83	8.713	2.170	14.77	8.50	10.75	6.676	5.13	2.628	1.583	0.366	5.957	3.402
8	113.49	100.91	40.498	30.063	103.11	45.10	103.08	74.756	43.37	28.979	15.828	3.663	59.567	34.017
9	2.46	1.92	1.936	1.219	2.22	1.10	0.88	0.158	0.63	0.230	0.143	0.039	1.034	0.448
10	127.16	64.92	615.100	57.640	404.26	100.48	188.15	47.730	250.91	94.470	444.460	225.310	453.660	50.740

1- Naphthalene, 2- Phenanthrene, 3– Anthracene, 4- Acenaphthylene, 5- Acenaphthelene, 6- Flourene, 7- Pyrene , 8- Chrysene, 9- Benzo[a]anthracene, 10- Fluoranthene.

nutrients, particularly nitrogen (Chan et al., 2008; Atagana, 2004), and SMS has the ability to degrade lignin and PAHs, a combination of poultry droppings and SMS degraded the PAHs better in the drill cuttings than with either amendment alone.

The higher the biodegradation rate constants, the faster the rate of biodegradation, and consequently, the lower the half-life times. It can be observed from Table 6 that among the reactors amended with poultry droppings (PD) + spent mushroom substrate (SD) and SMS, or with a combination of both amendments, reactor 6 exhibited a higher biodegradation rate constant (k) of 0.8073 week^{-1} and a lower half-life time (T1/2 = 0.86 weeks, R^2 = 0.135) for Acenaphthylene compared to other PAHs (Table 6). However, this was relatively followed by reactor 1, which was amended with animal source waste, PD + SD (k = 0.6548 week^{-1} and $T_{1/2}$ = 1.1 weeks, R^2 = 0.133), reactor 3 (k = 0.4455 week^{-1} and $T_{1/2}$ = 1.6 weeks, R^2 = 0.106), reactor 7 (k = 0.3427 week^{-1} and $T_{1/2}$ = 2.02 weeks, R^2 = 0.058), reactor 2 (k = 0.2785 week^{-1} and $T_{1/2}$ = 2.5 weeks, R^2 = 0.029), reactor 5 (k = 0.1551 week^{-1} and $T_{1/2}$ = 4.47 weeks, R^2 = 0.002) and reactor 4 (k = 0.1477 week^{-1} and $T_{1/2}$ = 4.7 weeks, R^2 = 0.066).

PAH ratios were calculated to determine PAH sources, clarify samples by locations, and estimate (Yunker et al., 2002). In Table 7, the calculated

Table 8. The biodegradation rate constant and half of the 14PAHs.

PAHs	PD + SD (4:1:1)		SMS (4:1:1)		PD + SD (4:1:2)		SMS (4:1:2)		PD +SD (4:1:4)		SMS (4:1:4)		(PD+SD) + SMS (4:1:1)	
	K_1	$T_{1/2}$	K_1	$T_{1/2}$	K_1	$T_{1/2}$	K_1	$T_{1/2}$	K_1	$T_{1/2}$	K_1	$T_{1/2}$	K_1	$T_{1/2}$
1	0.655	1.1	0.278	2.5	0.319	2.2	0.148	4.7	0.155	4.5	0.068	10.2	0.033	20.9
2	0.345	2.0	0.144	4.8	0.446	1.6	0.084	8.3	0.118	5.9	0.807	0.9	0.343	2.0
3	0.030	22.9	0.041	16.8	0.018	37.6	0.032	21.9	0.029	23.5	0.077	9.0	0.043	16.2
4	0.033	21.3	0.066	10.6	0.040	17.4	0.023	30.4	0.018	38.7	0.028	24.5	0.039	17.7
5	0.022	31.4	0.005	147.9	0.047	14.9	0.011	60.3	0.026	26.7	0.095	7.3	0.028	24.7
6	0.025	27.7	0.007	104.9	0.011	60.3	0.011	62.4	0.032	21.9	0.028	24.8	0.012	60.0
7	0.014	49.4	0.010	69.9	0.006	110.9	0.007	98.2	0.013	51.5	0.029	23.5	0.087	8.0
8	0.055	12.6	0.055	12.7	0.011	65.8	0.023	29.7	0.039	17.6	0.035	19.7	0.010	66.5
9	0.005	148.7	0.008	84.3	0.011	64.4	0.016	43.4	0.022	31.1	0.030	23.4	0.023	30.4
10	0.110	6.3	0.133	5.2	0.004	194.4	0.023	30.8	0.013	53.0	0.066	10.5	0.046	15.1
11	0.067	10.3	0.007	95.3	0.015	45.7	0.028	25.2	0.029	23.8	0.025	28.0	0.010	71.1
12	0.201	3.4	0.200	3.5	0.058	11.9	0.024	28.6	0.092	7.5	0.034	20.4	0.015	46.4
13	0.039	18.0	0.016	42.8	0.043	16.0	0.009	76.0	0.009	78.5	0.011	60.6	0.056	12.4
14	0.011	62.7	0.002	283.9	0.027	26.0	0.003	211.1	0.014	50.5	0.010	72.6	0.007	96.0

1- Naphthalene, 2- Acenaphthylene, 3- Acenaphthelene, 4- Flourene, 5- Phenanthrene, 6- Anthracene, 7- Fluoranthene, 8- Benzo[a]anthracene, 9- Chrysene, 10- Benzo[b]Fluoranthene, 11- Benzo[a]pyrene, 12- Indeno[1,2,3- cd]pyrene, 13- Dibenzo[a,h]anthracene, 14- Indeno[1,2,3-cd]pyrene.

ratios ∑LMW/∑HMW, Ant/(Ant+Phe), and BaA/(BaA+Chry) were observed to be <1, >0.1, and >0.35, respectively. These values may indicate that PAHs were primarily derived from anthropogenic and combustion sources. The B[a]Peq is the summation of the B[a]Peqi, calculated by multiplying the value for specific PAHs or individual PAH concentrations in the sample (cPAHi) by its toxic equivalency factor (TEFPAHi), as proposed earlier by Nisbet and Lagoy (1992) and Igbiri et al. (2017). TEF estimates the exposure risks modeled by individual and total PAHs to human health. In Table 8, the modeled values for the 10 PAHs indicate the exposure risk of total PAHs to human health at 8 weeks, which reduced to 32.05, 86.10, 69.21, 56.98, 57.85, 50.29, and 82.18% with the amended compost. The results indicate that compost with the specified ratios of plant and animal waste proved effective in reducing PAHs from crude oil waste (drill cuttings). However, the study suggests that extended remediation periods are advisable to maintain PAHs at a more reduced concentration and in an inactive form.

Furthermore, the study concludes that the majority of PAHs found in the environment are primarily a result of human activities, as indicated by the diagnostic ratios calculated. Notably, the half-life of the PAHs was reduced to less than a week for reactor 6, underscoring the significant impact of composting on the investigated PAHs.

Conclusion

The drill cuttings are deemed unsafe for land disposal without prior treatment. The current studies confirm that the use of plant residues and animal dung wastes, whether used alone or in combination, enhances the rate of petroleum hydrocarbon biodegradation in contaminated drill cuttings. In conclusion, a more pronounced effect was observed with the combination of poultry droppings and SMS, demonstrating better degradation of PAHs in the drill cuttings compared to the use of a single amendment.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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