

# Disappearance Time of a Few Polycyclic Aromatic Hydrocarbons in Soil

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*Received November 22, 2019; revised and accepted May 15, 2020*

**Abstract:** The present study attempts to determine the order of reactions for degradation of four polycyclic aromatic hydrocarbons viz., anthracene, fluorene, naphthalene and phenanthrene in six selected soil samples by method of trials. The half-life period or the disappearance times in days for 50% (DT 50) of the hydrocarbons initially applied to the soil were determined after finding out the probable order of the reactions using the half-life equations. A few of the extracts are subjected to GC analysis. Nine of 21 samples studied in the experiment are degraded and zero-order while the remaining samples are of the first order. The increasing trend in electrical conductivity and decreasing trend of pH support the formation of polar substances from non-polar hydrocarbons. Average DT 50 values for a mixture of the cited PAHs are 6 and 16 days, respectively, in presence of Fenton's Reagent and without it in the samples having 200 ppm concentration. In a semi-closed system, where there is no horizontal spread of solids and liquids, the DT 50 depends on initial pollutant concentration. Fenton's Reagent has been found to enhance the rate of degradation by the rapid conversion of the hydrocarbons into derivatives or fragments.

**Key words:** PAH degradation in soil, soil pH, Fenton's Reagent, order of degradation reactions, DT 50.

## Introduction

Emission of light gases to heavy residues from petroleum products, as well as a wide variety of hydrocarbons, are some common environmental contaminants (Coulon et al., 2010; PindadoJiménez et al., 2014). These compounds, once released into the environment, participate in different natural phenomena. The compounds with low molecular weight are normally subjected to volatilisation, but the heavier ones may gradually enter into the soil. After all, hydrocarbons from petroleum are the most common soil pollutants (Voyevoda et al., 2008). The experiments giving results of short-term degradation are sometimes depicted with the assumption of zero-order kinetics. However, for

a number of samples analysed at an interval of time sufficient for significant biodegradation to occur, the change in concentration of hydrocarbons with time is well illustrated by first-order kinetics. Presently, for the quantification of petroleum hydrocarbons, gas chromatography methods are the most used methods. Several studies have analysed petroleum hydrocarbons, particularly aromatic hydrocarbon, in soils (Roncevic et al., 2004).

Due to ubiquitous occurrence, persistency, the potential for bioaccumulation, detrimental nature, toxicity, mutagenicity and carcinogenicity, the PAHs have become a significant environmental concern (Haritash et al., 2009). A good number of efforts have been made to develop new, low-cost, less technical,

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eco-friendly treatments which will efficiently reduce and even eliminate PAH pollution in the atmosphere, hydrosphere and the lithosphere (Rao et al., 2010). Works have been carried out to lower the time required for decontamination of hydrocarbon pollution in the environment. Attempts have been made to examine bioremediation in presence of nutrients, oxidising agents from time to time. Experiments have been done to study the kinetics of degradation reactions and to find out DT 50 value i.e., disappearance time for 50% of the PAH just like the half-life period of a reaction (Thiele-Bruhn et al., 2005). The present experiment also intends to determine the order of a reaction and to determine DT 50 values with and without the presence of oxidising agent.

### Materials and Methods

Soil samples from different places are collected by adopting the standard procedure of sampling (Singh et al., 2000). The samples are air-dried, broken

down, pulverised and sieved (1 mm pore size) and homogenised by quartering process (Gupta, 2011). After all the processes, the sample amount becomes 2 kg, which are stored in polythene bag/beakers, labelled for experimentation. The physical parameters such as texture, bulk density (BD), particle density (PD), porosity, electrical conductivity (EC); chemical parameters such as pH, cations: sodium and potassium; soil organic carbon (SOC), soil organic matter (SOM), anions: chloride and sulphate by standard methods (Trivedy et al., 1987). Known quantities of anthracene, fluorene, naphthalene, phenanthrene and their mixture, chemical agents such as  $\text{CaCO}_3$ ,  $\text{CaSO}_4$  and Fenton's Reagent (FR) are mixed with soil (data quantity shown in Table 1). The PAH mixture contains equal masses of anthracene, fluorene naphthalene and phenanthrene and their solutions are prepared in dichloromethane (DCM). FR is prepared in 10:1 reagent ratio in which 1g of 30%  $\text{H}_2\text{O}_2$  (density  $1.1 \text{ g mL}^{-1}$ ) in 5 mL water is mixed with a solution of 0.1 g  $\text{FeSO}_4$  in 5 mL water at  $0^\circ\text{C}$ . The mixture is immediately added and the samples

**Table 1: Composition of samples**

<i>Sample No.</i>	<i>Mass of soil taken (<math>10^{-3}</math> kg) and code</i>	<i>Mass of pollutant added (<math>10^{-3}</math> kg) with name of the pollutant</i>	<i>Chemicals added (<math>10^{-3}</math> kg) with name</i>	<i>Total mass (<math>10^{-3}</math> kg)</i>	<i>Added pollutant concentration (ppm)</i>
1	777, A	8, Anthracene	15 g, $\text{CaCO}_3$	800	10,000
2	777, A	8, Anthracene	15 g, $\text{CaSO}_4$	800	10,000
3	792, A	8, Anthracene	0	800	10,000
4	777, A	8, Naphthalene	15 g, $\text{CaCO}_3$	800	10,000
5	777, A	8, Naphthalene	15 g, $\text{CaSO}_4$	800	10,000
6	792, A	8, Naphthalene	0	800	10,000
7	777, A	8, Fluorene	15 g, $\text{CaCO}_3$	800	10,000
8	777, A	8, Fluorene	15 g, $\text{CaSO}_4$	800	10,000
9	792, A	8, Fluorene	0	800	10,000
10	798.8, B	0.2, Mixture	100 mL, FR	800	200
11	799.8, B	0.2, Mixture	0	800	200
12	798.8, C	0.2, Mixture	100 mL, FR	800	200
13	799.8, C	0.2, Mixture	0	800	200
14	798.8, D	0.2, Mixture	100 mL, FR	800	200
15	799.8, D	0.2, Mixture	0	800	200
16	798.8, E	0.2, Mixture	100 mL, FR	800	200
17	799.8, E	0.2, Mixture	0	800	200
18	798.8, F	0.2, Mixture	100 mL, FR	800	200
19	799.8, F	0.2, Mixture	0	800	200
20	798.96, B	0.04, Mixture	10 mL, FR	800	50
21	799.96, B	0.04, Mixture	0	800	50

are mixed thoroughly.  $\text{CaCO}_3$  enhances the pH of the soil whereas  $\text{CaSO}_4$ , as well as FR, decreases the pH (Lin et al., 2016; Singh et al., 2000). A PAH solution (200 ppm) is prepared by dissolving 0.2 g each of the PAH in 75.37 mL DCM (density  $1.3266 \text{ g cm}^{-3}$ ) which is then added to soil to make up to a total of 800 g soil mixture. It is mixed thoroughly and kept open for natural degradation after moistening. Similarly, 10,000 and 50 ppm pollutant concentrations are also maintained as shown in Table 1.

At an interval of 10 days, the samples were agitated after moistening with an equal amount of water. After every 20 days, around 20 g accurately known quantity of the samples was taken for Soxhlet extraction using a mixture of solvents: DCM and petroleum ether in the proportion of 1:4. Since the solubility of aromatic hydrocarbons in DCM is higher than petroleum ether solvent, the extract was dissolved in DCM after complete removal of the Soxhlet solvent (Heleyur et al., 2016). The quantity of mixture soluble part in the blank soil is also determined and subtracted from those with PAH. After gravimetric determination, extracts are subjected to gas chromatographic analysis.

The total quantity of PAH applied could not be recovered by Soxhlet extraction done immediately after the mixing. The quantity so recovered informs the efficiency of the process. This figure is slightly different with different PAHs. It gives a number by which extracted quantities were multiplied later to get the actual amount of PAH present in the placed samples.

In order to determine the order of degradation reactions, the method of trials (Integration Method) for zero, first and second-order reactions are taken into consideration. Since the hydrocarbons are applied to a solid substance of comparatively large in quantity, the masses of the aromatic hydrocarbons were placed in the rate equations instead of molar concentrations. Thereafter the order of the reactions is ascertained by considering the most precise rate constant values. The expression for half-life period is taken as the basic equation for the calculation of DT 50 values (Table 2). The average rate constants of the selected order for a particular sample are taken as the rate constant for the concerned degradation reactions.

Gas-liquid chromatography was done on the DCM extract with the temperature programme on a Perkin Elmer GC. The GC conditions were as follows: an initial temperature  $100^\circ\text{C}$  for 2 minutes, and then a temperature ramp from  $100$  to  $350^\circ\text{C}$  at a rate of  $10^\circ\text{C}/\text{min}$ , and then kept at  $350^\circ\text{C}$  for a further 7 minutes in order to burn off any non-volatile organic compounds left in a total run time of 34 minutes.

**Table 2: The expressions for half-life periods of various ordered reactions**

Rate expression	Order	Half-life formula, DT 50
$k = x/t$	0	$T_{1/2} = [A_0]/2k$
$k = 2.303/t \cdot \log [A_0/x]$	1	$T_{1/2} = 0.693/k$
$k = 1/t \cdot [(A_0 - A)/A_0x]$	2	$T_{1/2} = 1/k[A_0]$

$A_0$  = initial concentration,

$k$  = rate constant,

$x$  = residual concentration

## Results and Discussions

Twelve physico-chemical parameters studied are shown in Table 3. One of the most important chemical parameters is pH. The values of pH in different types of soil indicate gradual increasing trend of acidic character in different types of soil:  $A < B < F < C < E < D$ , which means Residential Garden < River Bed < Horticultural Garden < Road Side < Paddy Field < Forest.

Since forest soil generally receives the largest quantity of plant residues per year that degrade over it, pH is expected to be of low value and is found accordingly (pH=4.67). This happens due to the production of oxygenated derivatives of organic substances that are mostly acidic, such as carboxylic acids, phenolic compounds, etc. The trends with respect to other parameters are as follows:

EC  $\longrightarrow D < B < C < F < E < A$

SOC  $\longrightarrow B < A < E < F < C < D$

Chloride  $\longrightarrow B < D < C < F < E < A$

Sulphate  $\longrightarrow B < C < D < F < E < A$

Sodium  $\longrightarrow B < A < D < F < C < E$

Potassium  $\longrightarrow A < B < C < D < F < E$

Here in most cases, it has been seen that the river bed soil is deficient in most of these chemical parameters of soil. The ionic nature of chloride, sulphate, sodium and potassium make them water-soluble and do not get adsorbed more in soil from running water.

Along with the highest acidity, forest soil also has the highest amount of SOC (3.15%). Contrary to it river bed soil is found to be deficient in organic carbon (0.07%). Although, pH value lower than 5 and SOC value outside the range of 1-3% signify problems in the soil with respect to plant growth due to unhealthy ratios between some nutrients and adverse effect on nutrient availability, the other physico-chemical parameters are in favourable range of microbial activities (Khan et al.,

**Table 3: Physico-chemical parameters of soil samples**

<i>Sample Code →</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>F</i>
<i>Source</i>	<i>Residential Garden</i>	<i>River Bed</i>	<i>Road Side</i>	<i>Forest</i>	<i>Paddy Field</i>	<i>Horticultural Garden</i>
Texture	Sandy Loam	Loamy Sand	Clay	Silty Clay Loam	Silty Clay Loam	Silty Clay Loam
EC, dSm <sup>-1</sup>	1.04	0.16	0.47	0.10	0.71	0.62
BD, 10 <sup>3</sup> kgm <sup>-3</sup>	1.52	1.43	1.62	1.4	1.93	1.92
PD, 10 <sup>3</sup> kgm <sup>-3</sup>	3.03	2.55	3.04	2.65	3.47	3.62
Porosity, %	50	44	47	47	44	46
pH	7.65	7.27	5.89	4.67	5.66	6.72
SOC, %	0.80	0.07	2.20	3.15	1.23	2.10
SOM, %	1.38	0.12	3.79	5.43	2.12	3.62
Cl <sup>-</sup> , ppm	196	80	113	85	128	120
SO <sub>4</sub> <sup>2-</sup> , ppm	1056	35	103	111	182	123
Na <sup>+</sup> , ppm	138	2	249	234	283	267
K <sup>+</sup> , ppm	16	27	88	91	115	110

2005). The ambient temperature of the region is also favourable for microbial activities in soil.

The Soxhlet extraction process to recover aromatic hydrocarbons from soil and its gravimetric measurement has certain loopholes. As such, the efficiency of the process adopted is determined first by recovering an aromatic hydrocarbon from a sample of soil instantly, where a known quantity of an aromatic hydrocarbon is applied. This efficiency determination experiment is done in different types of soil with different addendums including different concentrations of applied aromatic hydrocarbons. The efficiency of the gravimetric recovery process adopted is mostly in the range from 60 to 86 % (Table 4). The actual concentrations of aromatic hydrocarbons are higher than what is detected by the adopted process, hence, a factor called a multiplier is worked out to calculate the actual concentration of an aromatic hydrocarbon from its quantity detected by the experiment. The multipliers and its working are shown in the said table (Table 4).

The residual concentration of the hydrocarbons as recovered by Soxhlet extraction methods after 20, 40 and 60 days of placement are recorded in Table 5. It has been found that FR has a remarkable enhancement of degradation of the PAH. The mechanism of enhancement of degradation by FR is attributed to the production of lots of components/fragments or derivatives. It has been seen from the chromatograms that FR produces a lot of components from the PAH and gradually these degradation products vanish from the soil (Figures 1-3).

In order to monitor the effect of progressive degradation of aromatic hydrocarbons on pH and EC

of soil, the changes in pH and EC against time is monitored for samples numbering 8, 10, 12, 14, 16 and 18 having soils coded by A, B, C, D, E and F (Table 6). It has been seen that there is an increasing trend of EC and the decreasing trend of pH against time: 0, 20, 40 and 60 days. The increasing trend in electrical conductivity and decreasing trend of pH indicate oxidative degradation resulting in polar substance formation from non-polar ones. The role of FR in the process of oxidative degradation is important. Fenton oxidations are reportedly efficient in the acidic range from pH 3 to 4 that directly increases the concentration of Fe<sup>2+</sup> ion in the solution and the availability of •OH radicals for the desired reaction of oxidation of the pollutant (Kachieng, 2017; Lin, 2016).



Table 7 shows the rate constants for the degradation of PAH in first 20, 40 and 60 days assuming the order of the reaction to be 0, 1 or 2. The most precise set of rate constants is taken as the actual rate constants and the corresponding order of the reaction is considered to be the correct order of the reaction. In this treatment, nine reactions are of zero-order and the rest 12 are of first order. Here all the samples with 200 ppm exhibit a first order kinetics. Similar results have been reported by other workers (Nafie, 2007).

After ascertaining the order of the reaction, DT 50 values of the degradation process are calculated by using the integrated rate equation for the concerned order of a reaction. The disappearance time for 50% of the applied amount i.e., DT 50 values are shown in Table 8. It has

**Table 4: Calculation of efficiency of the process**

<i>a</i>	<i>b</i>	<i>C</i>	<i>d</i>	<i>e</i>	<i>F</i>	<i>G</i>	<i>h</i>
<i>Sample number</i>	<i>Soil code</i>	<i>Name of PAH</i>	<i>Quantity of PAH (<math>10^{-3}</math> kg)</i>	<i>In presence of</i>	<i>Recovered instantly (<math>10^{-3}</math> kg)</i>	<i>Efficiency of the process (100 f/d) %</i>	<i>Mutiplier (100 ÷ g)</i>
1	A	Anthracene	8	CaCO <sub>3</sub>	5.2416	65.52	1.53
2	A	Anthracene	8	CaSO <sub>4</sub>	6.4233	80.29	1.24
3	A	Anthracene	8	—	6.3500	79.38	1.26
4	A	Naphthalene	8	CaCO <sub>3</sub>	5.2320	65.40	1.53
5	A	Naphthalene	8	CaSO <sub>4</sub>	4.8033	60.04	1.66
6	A	Naphthalene	8	—	2.5961	32.45	3.08
7	A	Fluorene	8	CaCO <sub>3</sub>	6.7430	84.28	1.19
8	A	Fluorene	8	CaSO <sub>4</sub>	5.8000	72.50	1.38
9	A	Fluorene	8	—	5.6731	70.91	1.41
11	B	Mixture	0.2	—	0.172	86.00	1.16
13	C	Mixture	0.2	—	0.154	77.00	1.30
15	D	Mixture	0.2	—	0.131	65.50	1.53
17	E	Mixture	0.2	—	0.132	66.00	1.52
19	F	Mixture	0.2	—	0.123	61.50	1.63

**Table 5: Remaining concentrations of the hydrocarbons**

<i>a</i>	<i>B</i>	<i>c</i>	<i>d</i>	<i>E</i>	<i>F</i>	<i>G</i>	<i>h</i>
<i>Sample Number</i>	<i>Multiplier</i>	<i>at 20 days (<math>10^{-3}</math> kg)</i>	<i>at 40 days (<math>10^{-3}</math> kg)</i>	<i>at 60 days (<math>10^{-3}</math> kg)</i>			
		<i>Exptl</i>	<i>[c × b]</i>	<i>Exptl</i>	<i>[e × b]</i>	<i>Exptl</i>	<i>[g × b]</i>
1	1.53	3.9137	5.9880	2.5431	3.9680	1.2484	1.9490
2	1.24	4.0020	4.9623	2.4418	3.0279	1.4966	1.8558
3	1.26	3.8873	4.8980	2.2934	2.8897	1.3808	1.7398
4	1.53	3.7907	5.7998	2.3602	3.6111	0.9223	1.4112
5	1.66	3.4416	5.7131	2.0469	3.3980	0.6305	1.0466
6	3.08	1.9857	6.1160	1.3600	4.1889	0.7792	2.4001
7	1.19	4.9563	5.8980	3.1168	3.7090	1.3588	1.6170
8	1.38	4.3464	5.9980	2.7523	3.7990	1.2304	1.6980
9	1.41	4.2646	6.0132	2.8589	4.0311	1.4662	2.0673
10	1.16	0.0715	0.0199	0.0017	0.0020	0.0002	0.0002
11	1.16	0.0780	0.0905	0.0344	0.0408	0.0158	0.0183
12	1.30	0.0138	0.0179	0.0012	0.0016	0.0001	0.0001
13	1.30	0.0625	0.0813	0.0278	0.0361	0.0113	0.0147
14	1.53	0.0105	0.0161	0.0011	0.0017	0.0001	0.0002
15	1.53	0.0418	0.0639	0.0168	0.0257	0.0065	0.0100
16	1.52	0.0131	0.0199	0.0013	0.0020	0.0001	0.0002
17	1.52	0.0517	0.0779	0.0204	0.0310	0.0081	0.0123
18	1.63	0.0116	0.0190	0.0011	0.0018	0.0001	0.0002
19	1.63	0.0505	0.0823	0.0209	0.0341	0.0088	0.0144
20	1.16	0.0120	0.0139	0.0088	0.0102	0.0040	0.0046
21	1.16	0.0200	0.0232	0.0156	0.0180	0.0080	0.0092



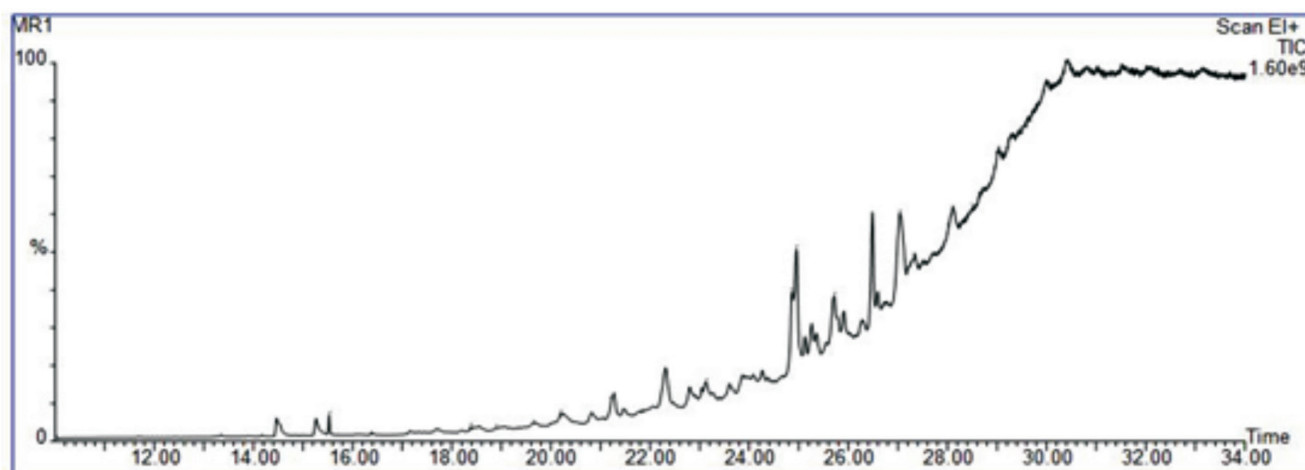


Figure 1: GC chromatogram of river soil and PAH at 0 day.

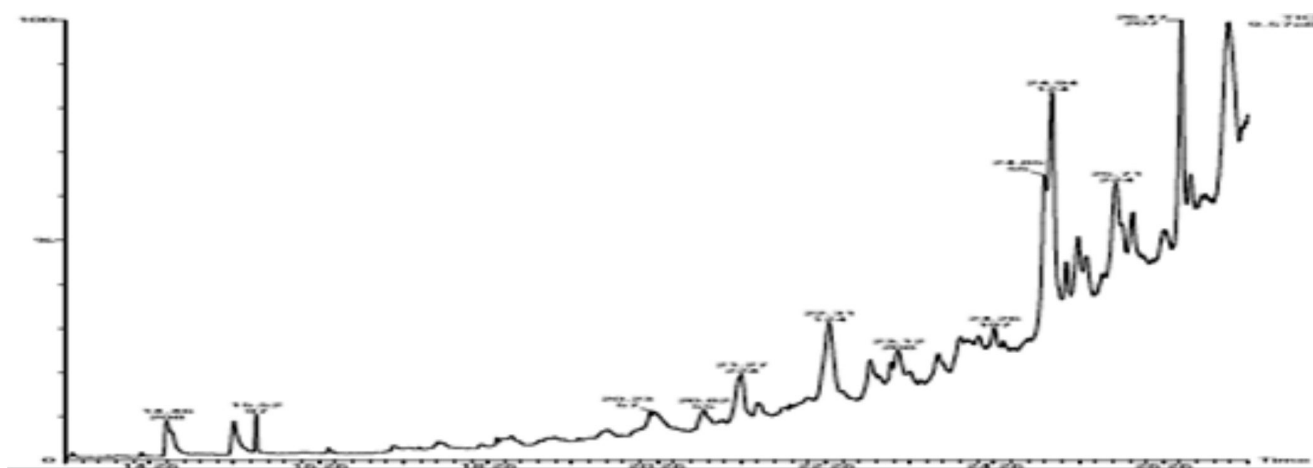


Figure 2: GC chromatogram of river soil, PAH and FR at 0 day.

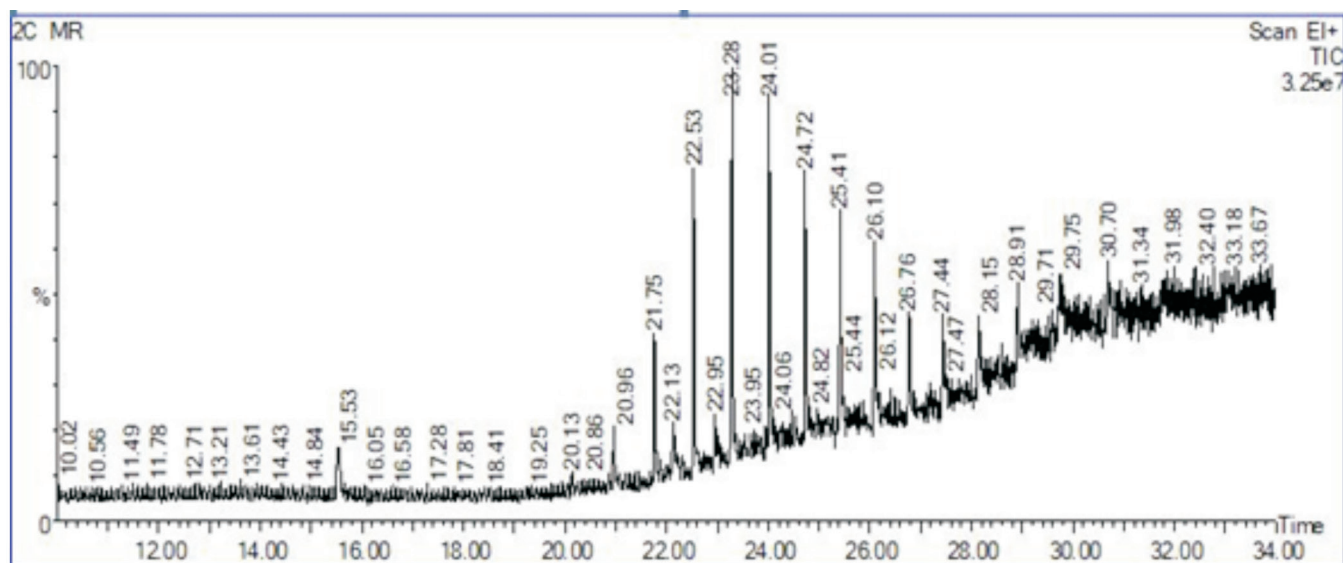


Figure 3: GC chromatogram of river soil, PAH and FR at 40 days.

**Table 6: Changes in electrical conductivity and pH**

Soil codes	pH values in days				EC (dS/m) in days			
	0	20	40	60	0	20	40	60
A	7.65	7.11	6.35	5.59	1.04	1.461	1.872	2.382
B	7.27	7.39	6.61	6.1	0.16	0.56	0.97	1.471
C	5.89	5.45	4.77	4.47	0.47	0.91	1.413	1.813
D	4.67	4.96	4.65	4.38	0.10	0.611	1.025	1.482
E	5.66	5.38	4.80	4.47	0.71	1.262	1.733	2.129
F	6.72	6.47	5.91	5.47	0.62	1.091	1.494	1.882

**Table 7: Rate constants of degradation reactions**

Sample Nos.	Order 0			Order 1			Order 2			Conclusion
	K1	K2	K3	K1	K2	K3	K1	K2	K3	Order
1	<b>0.1006</b>	<b>0.1010</b>	<b>0.1009</b>	0.0145	0.0206	0.0356	0.0021	0.0042	0.0130	0
2	0.1519	0.0967	0.0586	<b>0.0267</b>	<b>0.0247</b>	<b>0.0245</b>	0.0038	0.0064	0.0104	1
3	0.1551	0.1004	0.0575	<b>0.0245</b>	<b>0.0264</b>	<b>0.0258</b>	0.0039	0.0071	0.0114	1
4	<b>0.1100</b>	<b>0.1094</b>	<b>0.1099</b>	0.0161	0.0237	0.0469	0.0024	0.0052	0.0216	0
5	<b>0.1143</b>	<b>0.1157</b>	<b>0.1175</b>	0.0168	0.0260	0.5114	0.0025	0.0060	0.0033	0
6	<b>0.0942</b>	<b>0.0964</b>	<b>0.0894</b>	0.0134	0.0189	0.0278	0.0019	0.0038	0.0089	0
7	<b>0.1051</b>	<b>0.1094</b>	<b>0.1046</b>	0.0152	0.0232	0.0415	0.0022	0.0050	0.0174	0
8	<b>0.1001</b>	<b>0.1099</b>	<b>0.1050</b>	0.0140	0.0228	0.0403	0.0021	0.0048	0.0163	0
9	<b>0.0993</b>	<b>0.0991</b>	<b>0.0982</b>	0.0143	0.0200	0.0333	0.0021	0.0041	0.0118	0
10	0.0090	0.0009	0.0001	<b>0.1154</b>	<b>0.1149</b>	<b>0.1151</b>	2.2626	22.494	225.00	1
11	0.0055	0.0025	0.0011	<b>0.0397</b>	<b>0.0399</b>	<b>0.0401</b>	0.3025	0.6855	1.4472	1
12	0.0091	0.0008	0.0001	<b>0.1207</b>	<b>0.1211</b>	<b>0.1215</b>	2.5433	28.653	325.70	1
13	0.0059	0.0023	0.0011	<b>0.0451</b>	<b>0.0406</b>	<b>0.0450</b>	0.3650	0.7700	2.0233	1
14	0.0100	0.0007	0.0001	0.1260	<b>0.1124</b>	<b>0.1070</b>	2.8556	26.306	220.59	1
15	0.0068	0.0019	0.0008	<b>0.0571</b>	<b>0.0455</b>	<b>0.0470</b>	0.5326	1.1627	3.0364	1
16	0.0090	0.0054	0.0001	<b>0.1154</b>	<b>0.1154</b>	<b>0.1146</b>	0.4097	24.798	22.475	1
17	0.0061	0.0023	0.0009	<b>0.0471</b>	<b>0.0461</b>	<b>0.0462</b>	0.3918	0.9706	2.4527	1
18	0.0090	0.0009	0.0001	<b>0.1178</b>	<b>0.1172</b>	<b>0.1158</b>	2.3844	103.64	250.30	1
19	0.0059	0.0806	0.0334	<b>0.0444</b>	<b>0.0441</b>	<b>0.0431</b>	0.3575	0.8587	2.0060	1
20	<b>0.0013</b>	<b>0.0002</b>	<b>0.0003</b>	0.0529	0.0155	0.0398	23.471	1.3048	5.9676	0
21	<b>0.0008</b>	<b>0.0003</b>	<b>0.0004</b>	0.0272	0.0127	0.0336	0.9052	0.6226	2.6570	0

K1 – Rate constant at first 20 days; K2 – Rate constant at second 20 days; K3 – Rate constant at third 20 days.

been found that DT 50 of the samples where 10,000 ppm PAH was applied is in the range of 27 to 40 days. The same for 200 ppm concentration is in the range of 15 to 17 days in samples without FR while 6 days in samples where FR was applied. Here, the influence of FR as an oxidising agent for the degradation of aromatic hydrocarbons in the soil is reflected. The DT 50 values for 50 ppm was found to be 3 to 4 days. Average DT

50 values for a mixture of the cited PAHs are 6 and 16 days, respectively, in presence of Fenton's Reagent and without it in the samples having 200 ppm concentration (Table 9). The degradation of anthracene, naphthalene and fluorene is found to be enhanced by the application of calcium sulphate, which reduces the pH value. Thus, it indicates that at a slightly acidic pH, the degradation process has a slightly higher rate.

**Table 8: Calculation of DT 50 values of the polycyclic aromatic hydrocarbons**

Sample Nos.	Name of PAH	Soil Code	Addendum	Order of the reaction	K (average)	[R <sub>0</sub> ]	DT50 Days
1	Anthracene	A	CaCO <sub>3</sub>	0	0.1008	8	40
2	Anthracene	A	CaSO <sub>4</sub>	1	0.0253	8	27
3	Anthracene	A	---	1	0.0256	8	27
4	Naphthalene	A	CaCO <sub>3</sub>	0	0.1098	8	36
5	Naphthalene	A	CaSO <sub>4</sub>	0	0.1158	8	35
6	Naphthalene	A	---	0	0.0933	8	43
7	Fluorene	A	CaCO <sub>3</sub>	0	0.1064	8	38
8	Fluorene	A	CaSO <sub>4</sub>	0	0.1050	8	38
9	Fluorene	A	---	0	0.0989	8	40
10	Mixture	B	FR	1	0.1151	0.2	6
11	Mixture	B	---	1	0.0399	0.2	17
12	Mixture	C	FR	1	0.1211	0.2	8
13	Mixture	C	---	1	0.0436	0.2	16
14	Mixture	D	FR	1	0.1151	0.2	6
15	Mixture	D	--	1	0.0499	0.2	14
16	Mixture	E	FR	1	0.1151	0.2	6
17	Mixture	E	---	1	0.0465	0.2	15
18	Mixture	F	FR	1	0.1169	0.2	6
19	Mixture	F	---	1	0.0439	0.2	16
20	Mixture	B	FR	0	0.0006	0.04	3
21	Mixture	B	---	0	0.0005	0.04	4

**Table 9: Determination of average DT 50 values of the samples having mixture of PAHs with and without FR**

Sample Nos.	Without FR		Sample Nos.	With FR	
	DT 50 in days	Average		DT 50 in days	Average
11	17	16	10	6	6
13	16		12	8	
15	14		14	6	
17	15		16	6	
19	16		18	6	

### Conclusion

The abundance and carcinogenicity of some aromatic hydrocarbons has become a matter of serious concern. A few of them are said to be persistent in nature while several others are degradable. The rate of degradation is different for different hydrocarbons, mainly influenced by soil conditions and chemical reagents. Fenton's Reagent has a profound influence on degradation. At a lower concentration, the degradation of aromatic hydrocarbons in soil follows first-order kinetics. There are different processes of degradation, among which

bioremediation is considered as the most effective natural system. Opportunities exist for the aromatic hydrocarbons to enter the food chain if their degradation to harmless substances are longer.

### Acknowledgement

The authors are thankful to Assam Science Technology and Environment Council, Guwahati – 5 and Guwahati Biotech Park Incubation Centre, IIT Complex, Guwahati – 39.



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