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Integration of Oil Palm Fibre for remediation of Crude Oil Polluted Soil Environment

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ABSTRACT

The research work was carried out to investigate the effectiveness of the oil palm fibre for remediation of crude oil polluted environment of loamy soil. Analysis was conducted to determine the characteristics of the effectiveness of the oil palm fibre on the degradation of the crude oil in loamy soil environment. X-ray fluorescence spectrometer (GC) of *Elaeis guineeensis* and *Tekena Species* were examined and the result obtained revealed the presence of the following Mg, P, Si, S, K, and Ca within the energy level of > 0 to < 250J, Ti, Mn, Fe, Co, Ni, Cu and Zn within energy level range of > 250J to < 590J, W, Au, Pb, Rb, Zr, Nb, and Mo within energy level range of > 600J to< 1200J and Ag, Cd, Sn and Sb with energy level range of > 1400J to < 1800J. The micro-organism isolated and identified were fungi species with a population of $1.78x10^4 CFU.g^{-1}$ for *Elaeis guineeensis* and *Tekena Species* with a population of $1.2x10^5 CFU.g^{-1}$. The bacteria isolated and identified were with a population of $8.70x10^4 cfu.g^{-1}$ for *Elaeis guineeensis* and *Tekena Species* with a population of $9.0x10^6 CFU.g^{-1}$. It is observed that species are very effective when used for bioremediation of polluted soil environment. The Total Petroleum Hydrocarbon (TPH) in the loamy soil sample was examined for 0 to 84 days to ascertain the degree of degradation upon the influence of oil palm fibre characteristics to improve the level of restoration of the polluted loamy soil. A model was developed to determine the rate of degradation of contaminant with time. The result from the model validate the experiment with improved fibre sunlight 93.1%, local fibre sunlight 97.4%, and local with improve fibre 92.8% of the loamy soil contaminants.

Keywords: Integration, oil palm fibre, bioremediation, crude oil, polluted, soil environment

1. INTRODUCTION

The growing effect of environment pollution cause by crude oil activities is of concern to individual organization and Government. In restoring the environment inorganic materials like NPK fertilizer, use of detergent and controlled burning had being used despite its negative long term effect [1- 3]. This research work evaluates the performance of oil palm fibre in stimulating the growth of microbial organisms in degrading hydrocarbon present in crude oil contaminated soil hereby restoring the land to its original status [4 – 6]. The aim of the research work is to examine the effectiveness of the palm fibre powder concentration in remediating the polluted soil environment with petroleum hydrocarbon [7]. In this research work the following objectives were considered to: characterize the physicochemical parameters of the palm fibre powder used for the investigation, identify and isolate the possible microorganism present in the palm fibre powder, examine the rate of degradation of petroleum hydrocarbon upon the influence of microbes isolated and identified in the palm fibre powder sample used for the investigation, development of mathematical model interms of Micheal's Menten expression and testing of the palm fibre powder application for effective remediation approach [8 – 10].

Bioremediation enables micro-organisms to remove the toxic in organic contaminated areas by transforming harmful, undesirable and unwanted substance into non-toxic, harmless and environmental friendly compound [12 – 17]. The task of restoring our environment from oil spillage is now a global concern and hence approach adopted must meet global standard and practice [18]. However in 2010, the Nigeria government enacts the local content law to protect Nigeria oil and gas businesses and interests [19]. This law among other things adds value to Nigeria by the utilization of local raw material and human resources for the manufacturing of goods and provision of services to the industry [20 – 23]. On June 2, 2016 the Federal Government of Nigeria flag off the implementation of United Nation Environmental Pollution (UNEP) report in Ogoni land where the land, water and underground water has been contaminated and polluted with crude oil. With the setting up of hydrocarbon pollution Restoration Project (HYPREP) committee, all stake holders' hands are on deck to see to the success of the project [24 – 30].

The Niger Delta where the environment is polluted is blessed with abundance of palm trees from which the raw material (oil palm fibers) is used to restore the land [31 – 32]. This spurs my motivation for this work as: the raw materials are readily available, the environment will be restored at a far lower cost and less time, it will boost the economy of the Niger Delta in line with the objectives of the local content law and policy of the Federal Government and its findings will be relevant, now that Government agency cleaning up the Niger Delta area is on course starting with the Ogoni land [33 – 37].

The application of palm fruit fibre powder in remediating a crude oil polluted soil environment covers the scope stated below: sample collection of oil palm fibre and petroleum hydrocarbon, oil palm fibre subjected into room and atmospheric temperature, physiochemical analysis of the palm fibre powder from the process and the petroleum hydrocarbon used, X-ray fluorescence spectrometer analysis for the purpose of characterization of the palm fibre powder and petroleum hydrocarbon, experimental set-up of the main process, data collection from x-ray fluorescence spectrometer analysis results and other methods for metal determination as well as functional parameters examination and microbial analysis.

2. MATERIALS AND METHODS

This research details the material used in the experiment, the method, adopted, the model developed that predict the rate of degradation of contaminant with time.

Equipment, Materials and Reagents used

The following equipment, materials and reagent were used during this research work as stated; Oil palm fibers (*Elaesis guineensis* and *Tekena species),* Crude Oil (Bonny light), Glass wares, Weighing Beam, Stop clock, Bunsen burner, Loamy soil, P^H meter, Sky ray instrument (X-ray fluorescence spectrometer), Flame ionization detector, Bright field microscope, Polythene bag/foil paper, Incubator, Chromatographic column, Autoclave, Fridge, pentane, ethanol, iodine, hydrogen peroxide.

Experimental Procedures

Sample Collection

The sample used in this research work was collected as stated. The oil palm were collected from Agricultural Development Agency (ADP), Ahoada ,Rivers State while petroleum hydrocarbon was obtained from Eleme refinery, Rivers State .The loamy soil was tested and certified by soil science department, faculty of Agricultural, Rivers State University All were transported to the department of Chemical /Petrochemical engineering laboratory, Rivers State University Port-Harcourt for analysis. All necessary safety precaution was put in place while collecting all the samples to avoid contamination with other harmful substance.

Sample Treatment

Oil palm fibres were secured from the oil palm bunches of *Elaecis guineansis* (local) and *Tekena* species (improved from Agricultural Development Programme (ADP), Ahoada, Rivers State, herein refers and specimen A and B respectively. Each specimen was divided into parts.

Parts of specimen A and B were treated in the presence of direct sunlight while the other in the absence of sunlight (in a dark room). Both were allowed to dry. Each sub-specimen were crush separately with a grader and sieved with particle size of 2.80mm taken and tie in a polythene labeled as follows;

Specimen A: Local fibres sunlight, Specimen D: Improved fibres sunlight

Samples Analysis

Elements presence using x-ray fluorescence spectrometer

The elemental analysis was done using EDX3600B x-ray fluorescence spectrometer which applied XRF technology to conduct fast and accurate analysis of the sample. The system detects elements with atomic number 12 to 92. After pulverizing to homogenous size, it is calibrated using pure silver standard. Thereafter the working curve is selected using excel software and the output printed.

Type and quantity of micro-organisms presence per unit gram

One gram of each samples were diluted and plated, on one plate is inoculated with Nutrient Agar (NA) incubated at 37 for 24hrs, while the other is inoculated with Sabourand Dextrose Agar (SDA) were incubated at ambient temperature for 3-5 days. After incubation counts on the ensuing colonies on the NA and SDA plates were used to calculate the bacterial and fungal population with the formula below,

$$Population\left(\frac{CFU}{ml}\right) = \frac{colony\ count}{volume\ plated\ x\ dilution\ plated} \quad (1a)$$

The bacterial isolates were subjected to microscopic examination and biochemical/physiochemical tests. Similarly, fungal colonies that developed on SDA plates were incubated at ambient temperature for 3-5 days, thereafter the fungal isolates were subjected to macroscopic and microscopic examination.

The Total Petroleum Hydrocarbon (TPH)

Conversely, the Total Petroleum Hydrocarbon (TPH) was obtained by weighing 2grams of the sample and then 10ml of extraction solvent (pentane) was mixed, filtered and separated. The extracted samples were transferred to already prepare chromatographic column. Concentrated Aliphatic fractions were transferred through a rubber septum separation occur and samples are detected as it emerges from the column by Flame Ionization Detector (FID) whose response is dependent upon the composition of the vapor.

Experimental Set-up

In this Ex-situ remediation setup, four reactors were used for this experiment. Each reactor contains 20kg of loamy soil. Three out of the four reactors were polluted with 100ml of Bonny Light crude oil. Two out of the three polluted reactors were treated with 40kg of the various palm fibres concentration as demonstrated below (table 1).

Table1 Demonstration of Experimental Set-up

S/No	Reactors	Descriptions	Mass of fibres
1	A	Polluted loamy + improved fibres (sunlight)	40g
2	D	Polluted loamy soil + Local fibres (sunlight)	40g

3	F	Polluted loamy soil only	No fibres
4	G	Unpolluted loamy soil only	No fibres

These reactors were kept in the chemical engineering laboratory (unit operation) with the covering removed to allow for oxygen and humility for the enzymes in the fibres to grow. 100ml of tap water were added to the two reactors, A and D to maintain good moisture content for the microbes. Every five days the polluted samples A and D are mixed together to allow for even distribution of oxygen for effective remediation to take place. After two weeks each of the four samples were taken to the laboratory to analyze for the Total Petroleum Hydrocarbon (TPH). Polluted soil samples A, D and F were repeatedly analyze for P^H and Total Petroleum Hydrocarbon (TPH) after every 14 days (figure 1).

Experimental Diagrams

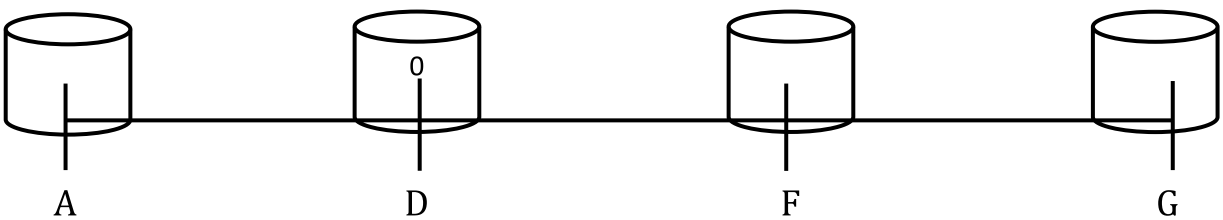


Figure1a Reactors A to G Containing 20kg of Loamy Soil

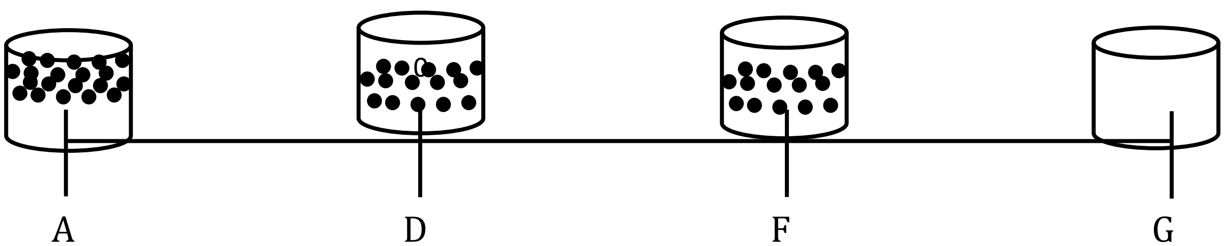


Figure1b Reactors A, D and F were Polluted with 100ml of Crude Oil while Reactor G Remains Unpolluted.

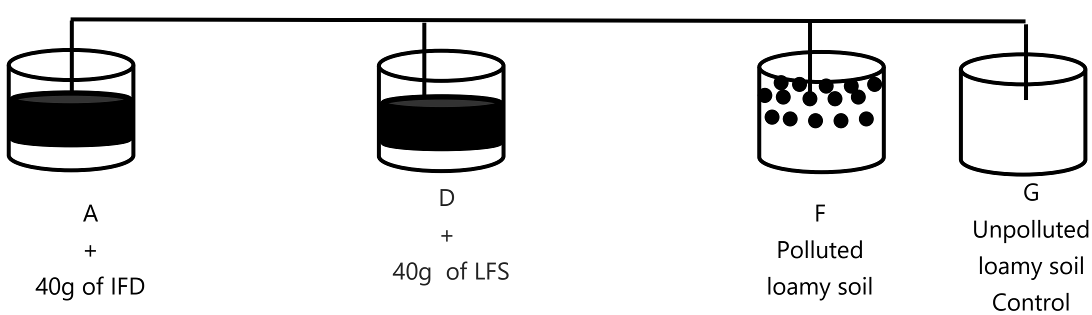
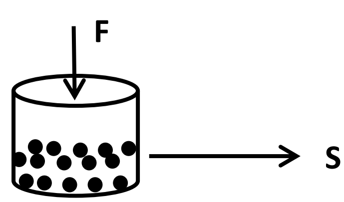


Figure1c Reaction A and D were Added with 40g of IFD, IFS, LFD, LFS and Equal Mixture of (IFS + IFD + LFD + LFS) Respectively

Kinetic Rate/Model Development



The palm fruits fibres (F) which nurture the microorganisms and enzymes and the substrate (S) in the medium undergo the reaction represented by

$$[F] + [S] \underset{K_1}{\overset{K_2}{\rightleftharpoons}} [FS] \xrightarrow{K_P} [F] + [P] \qquad (1)$$

Assumptions

1. Enzymes formed react with substrate forming enzyme substrate complex.
2. The Enzymes substrate decomposed to form product and enzymes.
3. The simple substrate controls the velocity of reaction.

Assuming 1st order reaction

$$\frac{d[FS]}{dt} = K_2 [F] [S] – K_1[FS] + K_p[F] + [P] \qquad (2)$$

Assuming steady state

$$0 = K_2 [F] [S] – K_1[FS] + K_p[F] + [P]$$

Rate of formation of [FS] is negligible, therefore $K_p = 0$

$$0 = K_2 [F] [S] – K_1 [FS]$$

But $K_s = \frac{k_1}{k_2}$

$$[F][S] = K_s [FS]$$

$$FS = \frac{[F][S]}{k_s}$$

Total Enzymes, $F_o = [F] + [FS]$ (3)

Speed (V) = K_p [FS] (4)

Resolving (3) and (4), we have

$$V = \frac{F_o K_P [S]}{K_s + [S]} \qquad (5)$$

At maximum rate of degradation (maximum velocity) $V_{max} = K_p[F_o]$ (6)

Therefore resolving equation (5) and (6), we have

$$\frac{V}{V_{max}} = \frac{[S]}{k_s + [S]} \qquad (7)$$

This is known as Henry-MichaelMenten equation.

$$v = \frac{V_{max}(S)}{Ks + [S]} \qquad (8)$$

Where, Vmax = Maximum specific rate, V = Specific rate, Ks = equilibrium constant

S = Substrate (TPH)

Applying the law of conservation of mass on the reaction process, we have.

[Rate of flow of mass into the system]	=	[Rate of flow of mass out of the system]	-	[Rate of disappearance by chemical reaction]	+	[Rate of generation by chemical reaction]	+	[Rate of Accumulation within the system]		(9)

Assumptions

The reactor above is batch, there is no inflow and outflow of mass, there is no longitudinal and lateral flow of mass and there is uniform concentration as the medium is stirred before samples are taken for TPH analysis. Hence; rate of inflow of mass = 0, rate of outflow of mass = 0, rate of formation = 0, rate of disappearing = $-r_A V$ and rate of accumulation of mass = $\frac{dNA}{dt}$

Substituting the above expression into equation (9), we have

$$0 = 0 + (-r_A)V + \frac{dNA}{dt} \quad (10)$$

$$\frac{-dNA}{dt} = (-r_A)V$$

$$\frac{-1}{v}\frac{dNA}{dt} = -r_A$$

But $\frac{NA}{v}$ = concentration(s), therefore

$$\frac{-dc}{dt} = \frac{-ds}{dt} = (-r_A)$$

But from equation (8) we have, ,$r_A = \frac{V_{max}[s]}{Ks+[s]}$

Therefore

$$\frac{-ds}{dt} = -v = \frac{V_{max}[s]}{Ks+[s]} \quad (11)$$

Equation (11) is the kinetic MichealMenten'smodel for determining rate of degradation of petroleum contaminants.

Where,$\frac{-ds}{dt}$ = change in concentration of contaminant measure in TPH with time.

Method of Solution to Model

Due to the complexity of the Monod rate equation developed, the Range – Kutta fourth order equation was used to obtain solution to rate equation. MATLAB computer program was used to solve the R – K equation and the algorithm is stated as follows:

$$S = f(t) \quad (12)$$

$$K_1 = hf\ (t(i), S(i)) \quad (13)$$

$$K_2 = hf\ (t(i) + \frac{h}{2}, s(i) + \frac{K1}{2} \quad (14)$$

$$K_3 = hf\ (t(i) + \frac{h}{2}, s(i) + \frac{K2}{2} \quad (15)$$

$$K_4 = hf(t(i) + h), s(i) + K_3 \quad (16)$$

$$S_{(i+i)} = S(i) + [k_1 + 2\ (k_2 + k_3) + K_4]\frac{n}{6} \quad (17)$$

Where, h = step size, n = number of iteration, t = time, S = TPH concentration,K_1, k_2, k_3, k_4 = slopes and i = 1, 2, 3, ... n

3. RESULTS AND DISCUSSIONS

In this research work results obtained are presented in Tables and Figures.

X-ray fluorescence spectrometer of *Ealeasis guineesis* and *Tekena* Species

Figure 2 and Figure 3 illustrates the Chromatogram result of the *Ealesis guineesis and Tekena species* and the percentage of potassium 0.416, phosphorus 1.23, calcium 3.810 for local palm fibre whereas the improved palm fibre values are obtained as potassium 2.3456, phosphorus 0.4398 and calcium 4.0510. This elemental value exceeds that of an organic matter in the ratio of 5:5:5 with respect to Nitrogen, Phosphorus and Potassium (NPK). This in terms of percentage is 0.33. This implies that the two species of palm fibres are good for bioremediation of crude oil polluted site.

X-ray fluorescence spectrometer (GC) of *Ealesis guineesis* and *Tekena* species

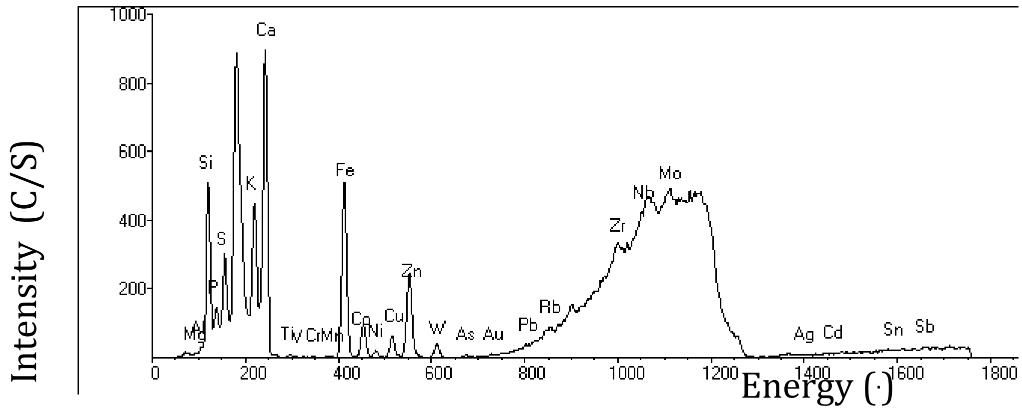


Figure 2 Chromatogram of *Ealesis guineesis*

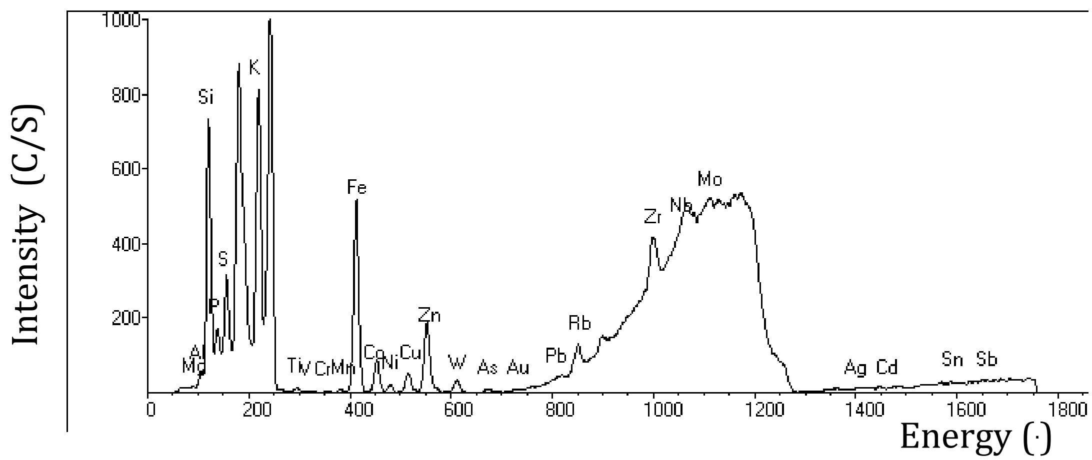


Figure 3 Chromatogram of *Tekena* Species

Determination of Kinetic Parameters

The specific rate, maximum specific rate and the Monod or Michealis constant were determined from the Line waver Burke Plots for each of the biodegradable material investigated from this research.

Determination of Rate constant for improved fibre sunlight

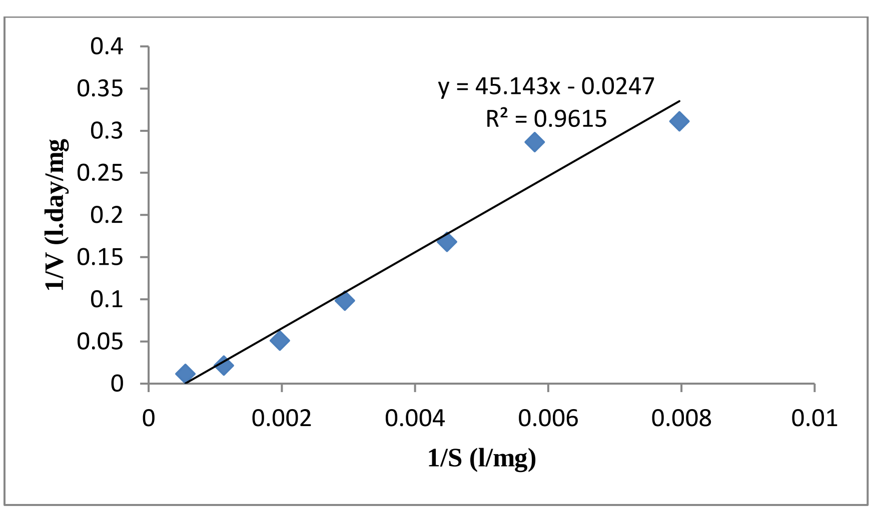


Figure 4 Line Waver Burke Plot for Improved Fibers (Sunlight)

From Figure 4 the line Waver Bulk Plot was used to determine the Kinetics parameters using improved fibre treated in sunlight. The equation of the line is given as y = 45.143x-0.0247 with the square of the best fit given as R^2=0.9615. From the calculation in the maximum specific rate was 40.49 Mg/L Day whereas the Michaelis constant was 1827.65mg/lg. Hence, the Kinetic model describing the biodegradation of TPH in polluted soil under the influence of improved fibre treated in the sunlight according to equation (8) can be expressed as $\frac{-ds}{dt} = -v = \frac{40.49[s]}{1827.65 + [s]}$

Determination of Rate constant for local fibre sunlight

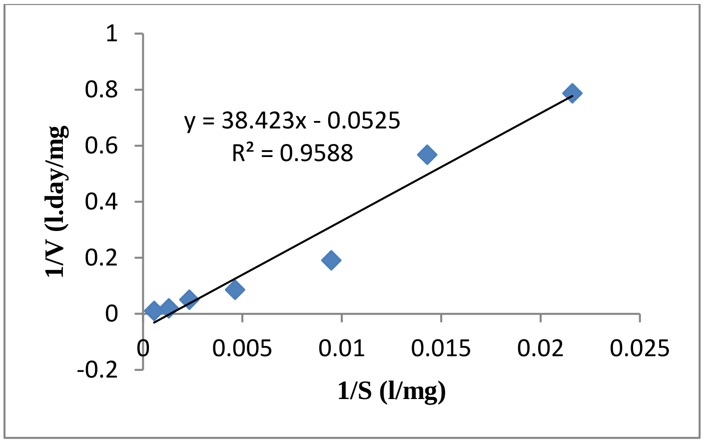


Figure 5 Line Waver-Burke Plot for Local Fibers (Sunlight)

The Figure 5 depicts the line Waver Burke Plot for the determination of the Kinetic rate parameters using local fibre treated in presence of sunlight. The equation of the line is given as y = 38.423x -0.0525 with the square of the best fit given as R^2=0.9588. From the calculations the maximum specific rate (V_{max}) was 19.05mg/L.day whereas the Michaelis constant (K_s) is 731.87 mg/lg. therefore the Kinetic rate model desorbing the biodegradation and TPH in polluted soil under the influence of local fibre according to equation (8) is given as: $\frac{-ds}{dt} = -v = \frac{19.05\ [s]}{731.81 + [s]}$

Determination of Rate constant for local and improved fibres (Sunlight)

The Figure 6 demonstrates the line Waver Burke Plot for the determination of the kinetic rate constant. The equation of the line is given as y = 45.464x – 0.0251 with the square of the best fit given R^2 = 0.9864. The maximum specific rate (V_{max}) was 39.84 mg/L.day whereas the Michealis constant (Ks) is 1811.31 mg/L. Therefore the kinetic rate model describing the biodegradation of TPH in polluted soil under the influence of local + improve fibre according to equation (8) can be expressed as $\frac{-ds}{dt} = -v = \frac{39.84\ [s]}{1811.31 + [s]}$

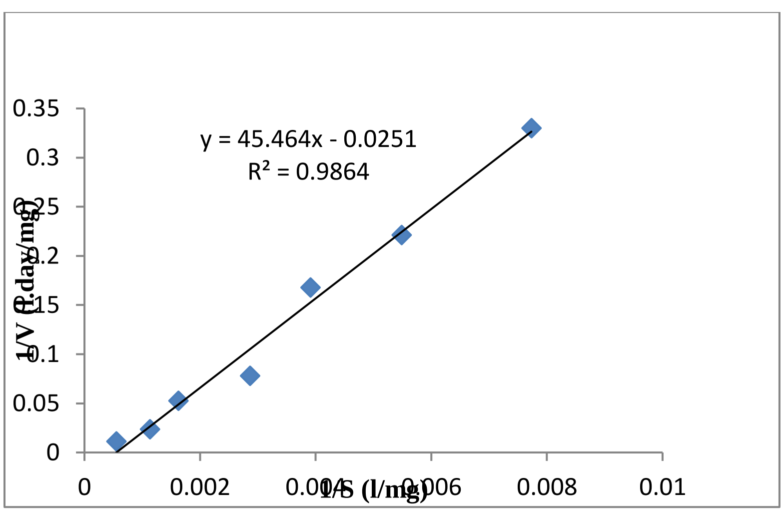


Figure 6 Line Waver-Burke Plot for Local + Improved Fibers (Sunlight)

Comparison of Model and Experimental Results

Data generated from the kinetic rate model for the different biodegradable materials used for the remediation of Petroleum Hydrocarbon in soil are shown in Figure 7 to 9. The TPH concentration of each biodegradable material is plotted against time (day).

Model and Experiment Performance for Improved Fibre Sunlight

The Total petroleum Hydrocarbon versus time shows decrease in contaminants with increase in time as presented in Figure 7. Figure 7 illustrates the comparison of experimental and the developed model result and the findings revealed the degradation of contaminant at 112.47mg/l for day zero. A sharp drop is observed at first 14ays. At 42 days investigation, the model degraded 1383.79 mg/l day investigation; the contaminant left is 125.47mg/l for experiment and 96.70mg/l for model. Hence percentage degradation for model is 94.7% whereas for the experiment is 93%. The percentage deviation of experiment and model is 22.9%. The result obtained shows a good match indicating the acceptability of the developed model in predicting, monitoring and simulating hydrocarbon degradation using oil palm fibre.

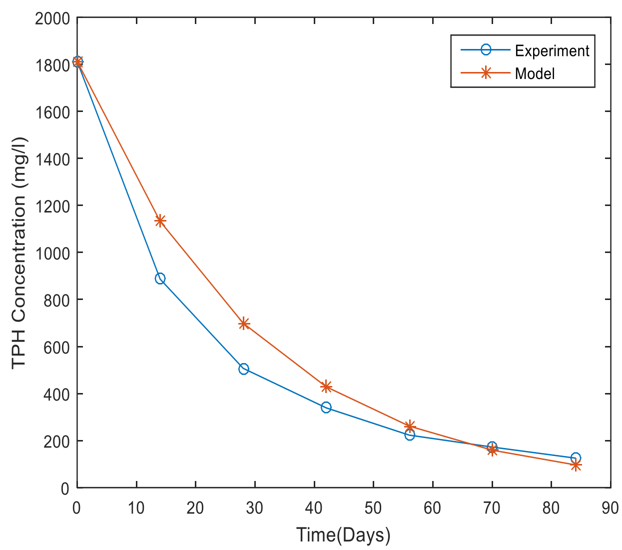


Figure 7 Performance of Improved Fibers (Sunlight) in TPH Reduction inSoil for Model and Experiment

Model and Experiment Performance for Local Fibre Sunlight

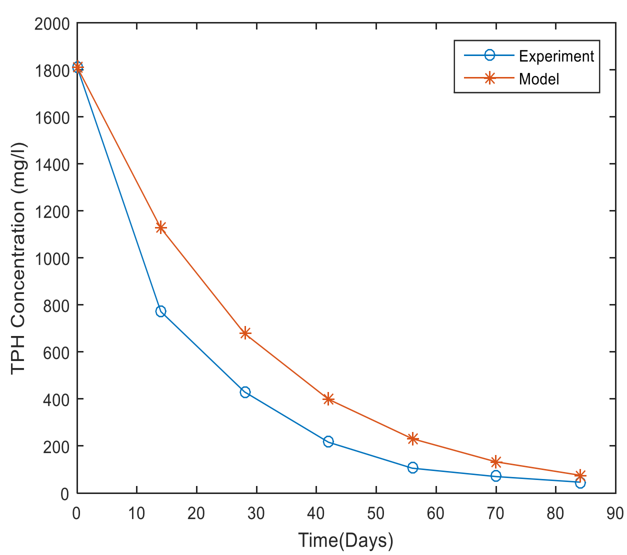


Figure 8 Performances of Local Fibers (Sunlight) in TPH Reduction in Soil for Model and Experiment

The experiment and model plot demonstrates the relationship TPC concentration and the result obtained revealed a slight difference in concentration of contaminant. The amount of contaminant degraded at day 84 as revealed by the model is

1736.80mg/l at 95.8% whereas for experiment is 1766.21mg/l at 97.45%. The percentage deviation of experimental data from model is 63%.

Model and Experiment performance for Local + improved Fibre

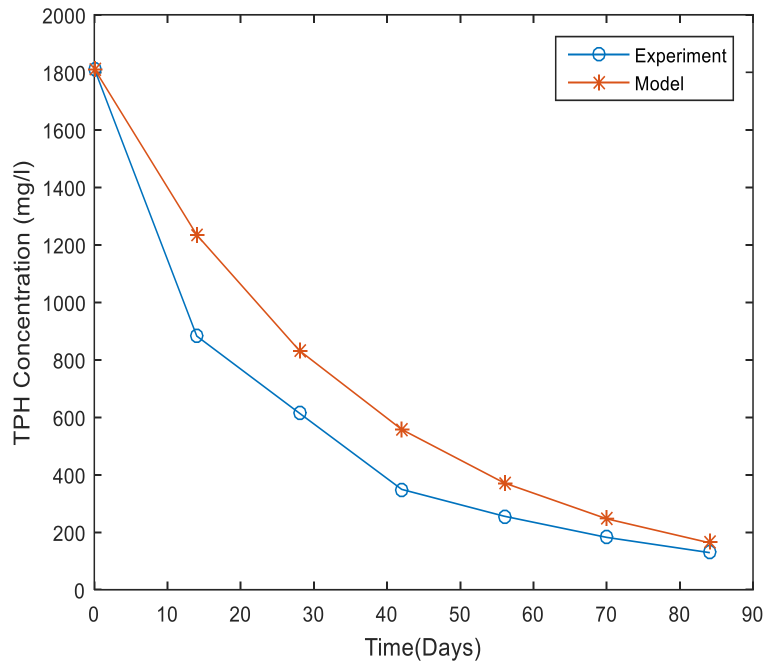


Figure 9 Performance of Combined Local and Improved Fibers in TPH Reduction in Soil for Model and Experiment

From Figure 9, both the model and experimental results the influence of time on degradation characteristics of the petroleum contaminant at concentration. The degradation value of the contaminant by model is 1648.8mg/l at 90.97% whereas the experimental value is given as 1683.12mg/l at 92.86%. The percentage deviation of experimental data from model is 26%. The individual petroleum hydrocarbon concentrations are presented in Table 2 to 5 for various operating conditions.

Table 2 Total Petroleum Hydrocarbon (TPH) of Polluted Loamy Soil + Improve Fibre (Sunlight)

COMPOUND NAME	DAY 0	DAY 14	DAY 28	DAY 42	DAY 56	DAY 70	DAY 84
n – C8	51.29429	3.65253	4.38315	3.62773	40.25017	15.17166	7.61762 e^{-2}
n – C9	1.59863	8.35660	14.20871	5.22263	3.88184	1.90134	6.63289 e^{-2}
n – C10	3.24104 e^{-1}	1-90328	5.43578	3.76589	5.99028 e^{-1}	4.58090 e^{-2}	7.70204 e^{-2}
n – C11	5.64908 e^{-2}	9.15168	18.41675	27.61546	4.73529 e^{-1}	4.30774 e^{-2}	8.13961 e^{-2}
n – C12	2.60017	105.55716	52.40140	11.47835	7.7540 e^{-1}	4.03774 e^{-1}	6.88413 e^{-2}
n – C13	4.38315	1.12744	453.67444	1.26655	6.13130 e^{-2}	1.06375 e^{-1}	7.48434 e^{-2}
n – C14	14.20871	14.77111	54.99857	29.16322	7.69427	6.33792 e^{-2}	9.19614 e^{-2}
n – C15	5.43578	1.21163	656.15852	5.83114	4.28139 e^{-1}	1.89396 e^{-1}	9.25309 e^{-2}
n – C16	18.41675	5.73230	33.68592	8.08046	1.51667	2.47101 e^{-1}	1.16878 e^{-1}
n – C17	52.40140	1.65166	60.89942	4.80138	3.31037	1.31134	1.94946 e^{-1}
Pristane	453.67444	4.46598 e^{-1}	10.51848	7.48470	3.59577	27.58404	2.53948
n – C18	54.99857	4.21269	4.24720	11.28242	7.05603	3.85951	3.84112 e^{-1}
phytane	656.15852	1.13394	42.75551	4.47027	63.78253	44.70520	4.68907 e^{-1}
n – C19	33.68592	3.91654	1.14305	3.94572	6.49091 e^{-1}	2.77795	2.53619 e^{-1}
n – C20	60.89942	4.51230	7.48016 e^{-2}	5.40881 e^{-1}	1.25979	4.63642 e^{-1}	1.97795 e^{-1}
n – C21	10.51848	1.6950	8.94577 e^{-1}	6.06416	3.70217	7.99193	1-09010
n – C22	4.24720	1.47949	6.66528	4-09650	4.94068	7.79753 e^{-2}	2.13331 e^{-1}

n – C23	42.75551	1.14163	5.26612 e^{-1}	3.82938	3.81461	1.28860 e^{-1}	2.46479 e^{-1}
n – C24	135.89143	1.46639	1.55225 e^{-1}	5.93404	2.85504	11.99911	3.18225 e^{-1}
n – C25	8.46000	1.75455	1.14096	6.81587	3.66622 e^{-1}	5.91329 e^{-1}	4.08630 e^{-1}
n – C26	8.80291	2.3460	1.16280	8.51230	9.11844 e^{-1}	8.23230 e^{-1}	4.87931 e^{-1}
n – C27	2.18632 e^{-1}	3.47281	2.05660 e^{-1}	15.54619	1.13223	5.99688 e^{-2}	5.71459 e^{-1}
n – C28	3.87470 e^{-1}	4.05977	5.9775 e^{-1}	4.67351 e^{-1}	7.67524 e^{-2}	8.91021 e^{-2}	7.75731 e^{-1}
n – C29	3.60934 e^{-1}	4.05977	1.36221 e^{-1}	1-61121	1.85738	3.21936 e^{-1}	1.04706
n – C30	6.92624	6.06744	3.79940 e^{-1}	1.35679	5.11268 e^{-1}	8.79031 e^{-1}	1-44611
n – C31	19.10384	8.99675	3.8574 e^{-1}	4.02129	1.29135	5.25135	3.14848
n – C32	8.77871	22.35790	4.30209 e^{-1}	8.89425 e^{-1}	9.55759	8.13457 e^{-1}	2.53285
n – C33	10.74807	3.85951	9.46108 e^{-1}	7.88911	4.52424	1.37472 e^{-1}	3.07148
n – C34	1.62491	44.70520	1.12744	5.75685	1.14660	3.4760 e^{-1}	3.81156
n – C35	6.7206	2.77795	14.77111	21.16835	3.89717	1.22227	5.09495
n – C36	11.95693	4.63642 e^{-1}	1.21163	3.543278	3.26449	2.08804	7.84975
n – C37	1.95874	7.99193	4.51230	2.431673	9.90778 e^{-1}	6.44836 e^{-1}	8.42511
n – C38	33.46704	7.79753 e^{-2}	1.6950	7.432679	14.58974	3.68674	13.39754
n – C39	15.01115	1.28860 e^{-1}	1.47949	1.765909	13.51473	5.27616	18.74781
n – C40	74.41567	3.01993	1.112354	4.37589	14.91637	31.09831	47.99298
$\sum(C_8\text{-}C_{40})$	1812.47426	886.45	507.21	339.09	223.19567	172.40215	125.45612

Table 3 Total Petroleum Hydrocarbon (TPH) of Polluted Loamy Soil + Local Fibre (Sunlight)

COMPOUND NAME	DAY 0	DAY 14	DAY 28	DAY 42	DAY 56	DAY 70	DAY 84
n – C8	51.29429	3.31037	20.81098	12.36533	28.77531	12.73233	2.8974 e^{-2}
n – C9	1.59863	3.59577	10.44368	1.89720	2.88743	1.95276	2.31024 e^{-2}
n – C10	3.24104 e^{-1}	7.05603	4.96533 e^{-1}	1.47330	2.19151 e^{-1}	1.71084 e^{-2}	3.04266 e^{-2}
n – C11	5.64908 e^{-2}	63.78253	16.26556	193.48174	2.15022 e^{-1}	2.7021 e^{-2}	3.17069 e^{-2}
n – C12	2.60017	6.49091 e^{-1}	9.41350	5.49272	5.54471 e^{-1}	4.81565 e^{-1}	3.18279 e^{-2}
n – C13	4.38315	1.25979	8.31821 e^{-1}	209.45719	8.09475 e^{-2}	1.07000 e^{-1}	3.49796 e^{-2}
n – C14	14.20871	3.70217	11.86693	6.43809	1.34059 e^{-1}	9.45682 e^{-2}	4.04701 e^{-2}
n – C15	5.43578	4.94068	1.93715	1.96893	2.61218 e^{-2}	1.61991 e^{-1}	3.97928 e^{-2}
n – C16	18.41675	3.81461	3.75928	4.58834 e^{-1}	2.39761 e^{-1}	1.55402 e^{-1}	4.05819 e^{-2}
n – C17	52.40140	2.85504	2.28923	7.50211 e^{-2}	5.84875 e^{-1}	1.14305	5.38037 e^{-2}
Pristane	453.67444	3.66622 e^{-1}	3.89430	6.63571	9.78473 e^{-1}	7.48016 e^{-2}	4.33565 e^{-2}
n – C18	54.99857	9.11844 e^{-1}	4.80744	58.8807	3.71738	8.94577 e^{-1}	7.76583 e^{-2}
phytane	656.15852	1.13223	2.18482	6.06786 e^{-1}	25.54469	6.66528	1.07695 e^{-1}
n – C19	33.68592	7.67524 e^{-2}	2.17987	1.30598	2.22560 e^{-1}	5.26612 e^{-1}	6.40762 e^{-2}
n – C20	60.89942	1.85738	2.38982	5.11472 e^{-1}	4.75522 e^{-1}	1.55225 e^{-1}	6.72024 e^{-2}
n – C21	10.51848	5.11268 e^{-1}	4.21044	10.51848	1.39647 e^{-1}	1.14096	1.18382 e^{-1}
n – C22	4.24720	1.29135	3.04070	4.24720	2.54486	1.16280	9.03058 e^{-2}
n – C23	42.75551	9.55759	4.80960	42.75551	2.34528	2.05660 e^{-1}	1.09674 e^{-1}
n – C24	135.89143	4.52424	2.72562	135.89143	1.68078	5.9775 e^{-1}	1.19179 e^{-1}
n – C25	8.46000	1.14660	9.65279 e^{-1}	8.46000	2.93295 e^{-1}	1.36221 e^{-1}	1.61874 e^{-1}
n – C26	8.80291	3.89717	3.69400	8.80291	4.36875 e^{-1}	3.79940 e^{-1}	2.44854 e^{-1}
n – C27	2.18632 e^{-1}	3.26449	2.37114	2.18632 e^{-1}	3.08553 e^{-1}	3.8574 e^{-1}	3.12355 e^{-1}
n – C28	3.87470 e^{-1}	9.90778 e^{-1}	2.63573	3.87470 e^{-1}	1.05568 e^{-1}	4.30209 e^{-1}	4.22405 e^{-1}
n – C29	3.60934 e^{-1}	14.58974	19.41939	3.60934 e^{-1}	4.32121 e^{-1}	9.46108 e^{-1}	6.09550 e^{-1}
n – C30	6.92624	13.51473	4.36800	6.92624	2.59994 e^{-1}	1.12744	1.47949
n – C31	19.10384	14.91637	2.24020	19.10384	6.93290 e^{-1}	14.77111	1.14163

n – C32	8.77871	6.81587	1.10508	8.77871	5.09573	1.21163	1.46639
n – C33	10.74807	8.51230	13.92289	10.74807	9.52959 e^{-1}	5.73230	1.75455
n – C34	1.62491	15.54619	316.92289	1.62491	3.3379 e^{-1}	1.65166	2.3460
n – C35	6.7206	4.67351 e^{-1}	3.68289	6.7206	1.79041	4.46598 e^{-1}	3.47281
n – C36	11.95693	1-61121	8.87702 e^{-1}	11.95693	4.24159 e^{-1}	4.21269	4.05977
n – C37	1.95874	1.35679	6.90258	3.87470 e^{-1}	3.65253	1.13394	4.05977
n – C38	33.46704	4.02129	9.80326	3.60934 e^{-1}	8.35660	3.91654	6.06744
n – C39	15.01115	8.89425 e^{-1}	3.17782	1.92624	1-90328	4.51230	8.99675
n – C40	74.41567	35.98636	13.8664	6.12568	9.15168	1.6950	22.35790
∑(C_8-C_{40})	1812.47426	771.56	429.83	216.11	105.55716	70.00306	46.26

Table 4 Total Petroleum Hydrocarbon (TPH) Of Polluted Loamy Soil + Mixtures of Local and Improved Fibre (Sunlight)

COMPOUND NAME	DAY 0	DAY 14	DAY 28	DAY 42	DAY 56	DAY 70	DAY 84
n – C8	51.29429	35.62491	11.86693	3.59577	30.07778	5.63673	4.36354e^{-2}
n – C9	1.59863	6.7206	1.93715	7.05603	3.69055 e^{-1}	6.85924 e^{-1}	13.99358
n – C10	3.24104 e^{-1}	7.95693	3.75928	63.78253	1.88646	1.27558 e^{-1}	4.37839 e^{-2}
n – C11	5.64908 e^{-2}	1.95874	2.28923	6.49091 e^{-1}	4.56182 e^{-1}	1.27675 e^{-2}	4.52506 e^{-2}
n – C12	2.60017	33.46704	3.89430	1.25979	5.99670 e^{-1}	1.54424 e^{-1}	4.83530 e^{-2}
n – C13	4.38315	15.01115	4.80744	3.70217	3.62773	4.90474 e^{-2}	5.04073 e^{-2}
n – C14	14.20871	4.41567	2.18482	4.94068	5.22263	1.52451	5.96849 e^{-2}
n – C15	5.43578	3.87495	3.76383 e^{-1}	3.81461	3.76589	4.14761 e^{-1}	6.52963 e^{-3}
n – C16	18.41675	8.4356	1.88560 e^{-1}	2.85504	27.61546	2.10155 e^{-1}	5.77801 e^{-2}
n – C17	52.40140	42.8494	1.25660 e^{-1}	3.66622 e^{-1}	11.47835	4.34170 e^{-1}	1.09220 e^{-1}
Pristane	453.67444	10.51848	20.81098	9.11844 e^{-1}	1.26655	66.61672	1.10267 e^{-1}
n – C18	54.99857	5.22632	10.44368	1.13223	29.16322	5.22091	1.22073
phytane	656.15852	5.72387	4.96533 e^{-1}	7.67524 e^{-2}	5.83114	71.32052	14.2720
n – C19	33.68592	6.99995	16.26556	6.43809	8.08046	1.931566	2.40872 e^{-1}
n – C20	60.89942	3.88184	3.75928	1.96893	4.80138	6.17126 e^{-1}	9.28820 e^{-1}
n – C21	10.51848	5.99028 e^{-1}	2.28923	4.58834 e^{-1}	7.48470	2.98832	1.20212 e^{-1}
n – C22	4.24720	4.73529 e^{-1}	3.89430	7.50211 e^{-2}	11.28242	5.1310 e^{-1}	8.36707 e^{-1}
n – C23	42.75551	7.7540 e^{-1}	4.80744	6.63571	4.47027	1-79830	3.42382 e^{-1}
n – C24	135.89143	6.13130 e^{-2}	2.18482	58.8807	3.94572	1.39745	2.81812 e^{-1}
n – C25	8.46000	6.67444	3.76383 e^{-1}	6.06786 e^{-1}	5.40881 e^{-1}	1-58805 e^{-1}	2.40523 e^{-1}
n – C26	8.80291	54.99857	1.88560 e^{-1}	1.30598	6.06416	2-7556 e^{-1}	3.36269 e^{-1}
n – C27	2.18632 e^{-1}	6.15852	1.25660 e^{-1}	5.11472 e^{-1}	4-09650	1.2582 e^{-1}	4.25930 e^{-1}
n – C28	3.87470 e^{-1}	33.68592	20.81098	10.51848	3.82938	1.92922 e^{-1}	5.74343 e^{-1}
n – C29	3.60934 e^{-1}	2.89942	10.44368	4.24720	5.93404	4.13958 e^{-1}	7.47218 e^{-1}
n – C30	6.92624	10.51848	4.96533 e^{-1}	42.75551	6.81587	4.82493 e^{-1}	1.14759
n – C31	19.10384	4.24720	16.26556	135.89143	8.51230	1.26079 e^{-1}	2.32911
n – C32	8.77871	42.75551	9.41350	8.46000	15.54619	5.88606 e^{-1}	1.91087
n – C33	10.74807	135.89143	8.31821 e^{-1}	8.80291	4.67351 e^{-1}	9.24123 e^{-2}	2.38663
n – C34	1.62491	2.85754	11.86693	2.18632 e^{-1}	1-61121	2-86220 e^{-1}	2.90000
n – C35	6.7206	5.95472	1.93715	3.87470 e^{-1}	1.35679	2.70103	4.05568
n – C36	11.95693	10.6321	3.75928	3.60934 e^{-1}	4.02129	1-36828	6.00303
n – C37	1.95874	3.82738	4.58834 e^{-1}	2.87352	8.89425 e^{-1}	4.71550 e^{-1}	6.86936
n – C38	33.46704	25.9846	7.50211 e^{-2}	6.98473	7.88911	7.91828	9.93670
n – C39	15.01115	12.6453	10.987463	5.86735	5.75685	5.20392 e^{-1}	16.24201
n – C40	74.41567	32.6735	20.48374	18.7859	21.16835	5.71892	41.20436

$\sum(C_8\text{-}C_{40})$	1812.47426	882.46	614.73	349.08	255.86477	182.20342	129.35312

Table 5 Total Petroleum Hydrocarbon (TPH) Of Unpolluted Loamy Soil

COMPOUND NAME	AMOUNT(PPM)
n – C8	2.45920
n – C9	$2.49307e^{-1}$
n – C10	$1.48258\ e^{-2}$
n – C11	$3.05302\ e^{-2}$
n – C12	$5.447800\ e^{-2}$
n – C13	$1.08552\ e^{-2}$
n – C14	$6.17979\ e^{-3}$
n – C15	$2.24392\ e^{-3}$
n – C16	$4.87702\ e^{-3}$
n – C17	$1.49334\ e^{-2}$
Pristane	$3.49109\ e^{-2}$
n – C18	$1.60516\ e^{-2}$
Phytane	$2.81852\ e^{-1}$
n – C19	$2.17205\ e^{-3}$
n – C20	$1.19569\ e^{-2}$
n – C21	$1.14167\ e^{-2}$
n – C22	$2.13811\ e^{-2}$
n – C23	$1.10917\ e^{-2}$
n – C24	$4.66852\ e^{-3}$
n – C25	$1.41625\ e^{-2}$
n – C26	$4.63576\ e^{-3}$
n – C27	$2.07265\ e^{-3}$
n – C28	$5.04353\ e^{-2}$
n – C29	$3.20834\ e^{-2}$
n – C30	$1.92537\ e^{-2}$
n – C31	$5.63731\ e^{-2}$
n – C32	$2.25421\ e^{-1}$
n – C33	5.52479
n – C34	$7.07953\ e^{-1}$
n – C35	$1.24313\ e^{-1}$
n – C36	$7.80203\ e^{-2}$
n – C37	$4.82216\ e^{-2}$
n – C38	$8.32206\ e^{-1}$
n – C39	$9.15740\ e^{-1}$
n – C40	$3.01718\ e^{-1}$
$\sum(C_8\text{-}C_{40})$	12.18052

4. CONCLUSION

Bioremediation of crude oil polluted loamy soil using oil palm fibre is proven to be very effective in restoring the soil to its original status. Palm fruit fibres of *Elaeis guineeensis* and *Tekena Species* have gives an NPK values good enough for remediation. Palm fruit fibre species treated at various conditions degraded the petroleum Hydrocarbon at different rate by measuring the total petroleum Hydrocarbon (TPH).

The research work demonstrates the usefulness of palm fibre dried in sunlight temperature. The findings reveal that palm fibre powder of *Tekena Species* and *Eleais guineensis* treated in Sunlight, and a mixture of both *Ealesis guineesis* and *Tekena Species* are more effective in remediating the polluted loamy soil with petroleum hydrocarbon. Microorganism such as *Mucor* sp, *cunninhamella* sp and *verticillium* sp are effective micro-organism for bioremediation. This effectiveness can be attributed to the effect of sun energy on the nutrient in the palm fibre concentration.

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