

Kinetics of Soil Contaminant Degradation Enhanced by *Jatropha Tanjorensis* Leaf Bio-Stimulant

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Abstract

The data obtained from the experiment show a high viability of the plant extracts in the biodegradation process, the maximum specific rate was determined. Also, application of Michael Menten's equation were also applied, the maximum dissociation rate constant was obtained from Lineweaver bulk plot, for both sun-dried and room dried at 100 g of CPED and CPEL as R_{MAX} to be 1000 ppmday^{-1} and $555.55 \text{ ppmday}^{-1}$ whereas K_{PTH} 3190.16 ppm^{-1} and 5316.8 ppm^{-1} for loamy soil and R_{max} $476.1905 \text{ ppmday}^{-1}$ and $500.672 \text{ ppmday}^{-1}$ while K_{TPH} $2022.399 \text{ ppm}^{-1}$ and 1890.2 ppm^{-1} for sand soil. Hence the result obtained reveal that the remediant with the high dissociation constant (loamy soil) has performed brilliantly than the other plant extract. The mass of the biostimulant was varied from 20 g to 100 g and the performance of the remediants were monitored in each bioreactor with respect to the total petroleum hydrocarbon degradation with increase in contact time. Regression equation obtained in each bioreactor experience was used in the determination of the slope and the intercept value as well as substituted in the determination of the functional parameters and coefficients. The significance of the biokinetics concepts in the bioremediation system is to evaluate the kinetic parameters, which include the specific rate of total petroleum hydrocarbon degradation, maximum specific rate of total petroleum hydrocarbon degradation as well as the equilibrium constant of the total petroleum hydrocarbon.

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INTRODUCTION

In recent times research carried out on the remediation of crude oil contaminated soils environment has revealed the viability of plants extract in mitigating total petroleum hydrocarbon. The incessant oil exploitation and exploration has increased the rate of contamination of the environment, therefore there is need to remedy the environment [1-2]. There are several methods employed in remediation of the contaminated environment, such as chemical remediation and mechanical remediation [3]. Some of these methods of cleaning up the environment have not totally restored the environment completely; these inadequately were seen through stunted growth of plants, unyielding crops, draught of crops before maturity. Also, chemicals are re-introduced to the environment in cause of cleaning up the contaminant, thereafter these chemicals in combination with the contaminant were distributed to other parts of the environment [4]. Likewise, the

dig and dumped method also accounts for the redistribution of the contaminant. Hence to avoid the act of distorting the soil profile, transferring of the contaminant from one point to another for treatment. Hence the technique that is most environmentally friendly such as the plant extract method of bioremediation should be employed [5-6]. Hence locally sourced plant extract of Chaya plant which is like *Justicia carnea* is suitable to serve as alternative plant extract for biodegradation of crude oil contaminated soil [7]. This study was intended to provide an alternative technique for, bioremediation of contaminated soil environment using Chaya plant extracts (*Jatropha tanjorensis*).

Bioremediation enables micro-organisms to remove the toxic in organic contaminated areas by transforming harmful, undesirable and unwanted substance into non-toxic, harmless and environmentally friendly compound [8-10]. The task of restoring our environment from oil spillage is now a global concern and hence approach adopted must meet global standard and practice. However, in 2010, the Nigeria government enacts the local content law to protect Nigeria oil and gas businesses and interests. 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. 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 are on desk to see to the success of the project [11-13].

MATERIALS AND METHODS

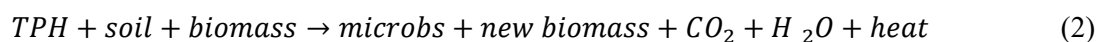
The Microbial Kinetics

The application of microbe on a biodegradable substance results a biochemical reaction, at a steady state condition using the general conservation principle of steady state to give rise to unstable state. Equation 1

$$\left[\begin{array}{c} \text{rate of oil} \\ \text{contaminated} \\ \text{in the soil} \end{array} \right] - \left[\begin{array}{c} \text{rate of oil} \\ \text{leaving} \\ \text{the soil} \end{array} \right] - \left[\begin{array}{c} \text{rate of oil} \\ \text{consumption} \\ \text{by microbes} \end{array} \right] = \left[\begin{array}{c} \text{rate of oil} \\ \text{accumulation} \\ \text{in the soil} \end{array} \right] \quad (1)$$

Using a batch reactor system, the following consideration were made;

$$\begin{array}{l} \text{rate of oil} \\ \text{contaminated} \\ \text{in the soil} \end{array} = 0 \text{ and } \begin{array}{l} \text{rate of oil} \\ \text{leaving} \\ \text{the soil} \end{array} = 0$$



. Biodegradation of crude oil is usually explained by first-order kinetics as given in the equation below.

The following conventions were taken into consideration) A batch reactor was considered

b) The process was stirred thoroughly every 7 days

Equation (2) can be expressed using the rate equation.

$$\frac{dTPH}{dt} = -k(TPH - TPH)^n \quad (3)$$

where:

TPH = substrate (contaminant) concentration at a given time, k = reaction rate constant

n = order of reaction., TPH_{∞} = minute concentration of the substrate

Considering a zero order reaction where $n = 0$ equation (3) becomes

$$\frac{dTPH}{dt} = -k(TPH - TPH_{\infty})^0 \quad (3a)$$

Rearranging equation (3a), we have

$$\frac{dTPH}{(TPH - TPH_{\infty})^0} = -kdt \quad (4)$$

$$dTPH = -kdt \quad (5)$$

Taking the integral of equation (4,5) with the boundary's conditions

$$\int_0^{TPH} dTPH = -k \int_0^t dt \quad (6)$$

$$TPH - TPH_0 = -kt \quad (7)$$

$$TPH = TPH_0 - kt \quad (8)$$

$$k = \frac{TPH_0 - TPH}{t} \quad (9)$$

Considering when the reaction rate is of the 1st order that is when $n = 1$, equation (6-8) will be transformed to:

$$\frac{dTPH}{TPH - TPH_{\infty}} = -kdt \quad (10)$$

Equation (9) can be further simplified with the boundaries condition to:

$$\int_0^{TPH} \frac{dTPH}{TPH - TPH_{\infty}} = \int_0^t dt \quad (11)$$

$$\ln \frac{TPH - TPH_{\infty}}{TPH_0 - TPH_{\infty}} = -kt \quad (12)$$

$$\frac{TPH - TPH_{\infty}}{TPH_0 - TPH_{\infty}} = e^{-kt} \quad (13)$$

Equation (10-12) can be further simplified by multiplying both sides by $TPH_0 - TPH_{\infty}$

$$TPH - TPH_{\infty} = (TPH_0 - TPH_{\infty})e^{-kt} \quad (14)$$

Assuming that the biodegradation actually removed all the substrate (contaminant) which implies that the concentration of the substrate in the soil is zero, that is TPH_{∞} is zero. Equation (13-14)

$$TPH = TPH_0 e^{-kt} \quad (15)$$

When the final concentration of the substrate in the soil is not zero, that is $TPH_{\infty} \neq 0$ equation (15) yields

$$TPH = TPH_{\infty} + (TPH_0 - TPH_{\infty})e^{-kt} \quad (16)$$

Considering a general n^{th} order equation, the rate equation for the batch bioreactor used is given by Equation (16)

$$\frac{dTPH}{(TPH-TPH_{\infty})^n} = -kdt \quad (17)$$

Taking the integral of equation (17), we have

$$\int_0^{TPH} \frac{dTPH}{(TPH-TPH_{\infty})^n} = -k \int_0^t dt \quad (18)$$

$$\frac{(TPH-TPH_{\infty})^{1-n} - (TPH_0-TPH_{\infty})^{1-n}}{1-n} = -kt \quad (19)$$

$$(TPH - TPH_{\infty})^{1-n} = (TPH_0 - TPH_{\infty})^{1-n} - (1 - n)kt \quad (20)$$

Assuming that ultimate substrate concentration reduces to zero equation (18-20) becomes

$$TPH^{1-n} = TPH_0^{1-n} - (1 - n)kt \quad (21)$$

Equation (21) can be used to predict the rate of substrate biodegradation of crude oil contaminated soil at given time interval. The value of k and n can be evaluated using the fractional (F) conversional method.

$$\text{where } F = \frac{TPH}{TPH_0} \quad (22)$$

Rearranging equation (22), and making T_f the subject, we have

$$T_f = \frac{F^{1-n}}{k(n-1)} TPH_0^{1-n} \quad (23)$$

where: T_f = the fractional conversion factor, k = rate constant and n = order of reaction

Taking the ln of both side of equation (23), gives

$$T_f = \left(\frac{F^{1-n}}{k(n-1)} \right) + (n - 1) \ln TPH_0 \quad (24)$$

The value of n is gotten by plotting the graph of $\ln T_f$ against $\ln TPH_0$, which gives the slope as $(n-1)$ with these variables the value of n can be evaluated. The value of k is therefore obtained by substituting the value of n and other parameters. Equation (24)

The substrate concentration can be co-related to Michael Menten equation.

$$R = \frac{R_{max}[TPH]}{k_{TPH} + [TPH]} \quad (25)$$

Translating equation (25) into line waver Burk plot by taking the inverse of equation (3.26)

$$\frac{1}{R} = \frac{k_{TPH} + [TPH]}{R_{max}[TPH]}$$

RESULTS AND DISCUSSION

The result obtained from this investigation are presented in Figures and Tables as demonstrated in this research. However, the results demonstrated in Tables are shown in the appendix.

Figure 1 demonstrate the line weaver bulk plot of reactor A₂₀ containing (20 g CPED). A plot of the inverse of the rate of degradation ($\frac{1}{R}$) against the reciprocal of the TPH degraded or substrate ($\frac{1}{S}$) is gives as linear equation of the form $y = 0.33x + 0.0001$ with R^2 value of 0.66 . The functional parameter of the line weaver bulk plot deduced from the linear graph were K_S and R_{max} . The value for R_{max} is evaluated as the $\frac{1}{R_{max}} = intercepts$, hence the R_{max} is give as the inverse of the intercept which is equal to 10000, likewise the value of K_{TPH} for reactor B₂₀ (20 g CPEL) is evaluated $\frac{K_{TPH}}{R_{max}} = slope$, therefore $K_{TPH} = 3053ppm^{-1}$ and Figure 1 obeys the lineweaver Bulk Plot.

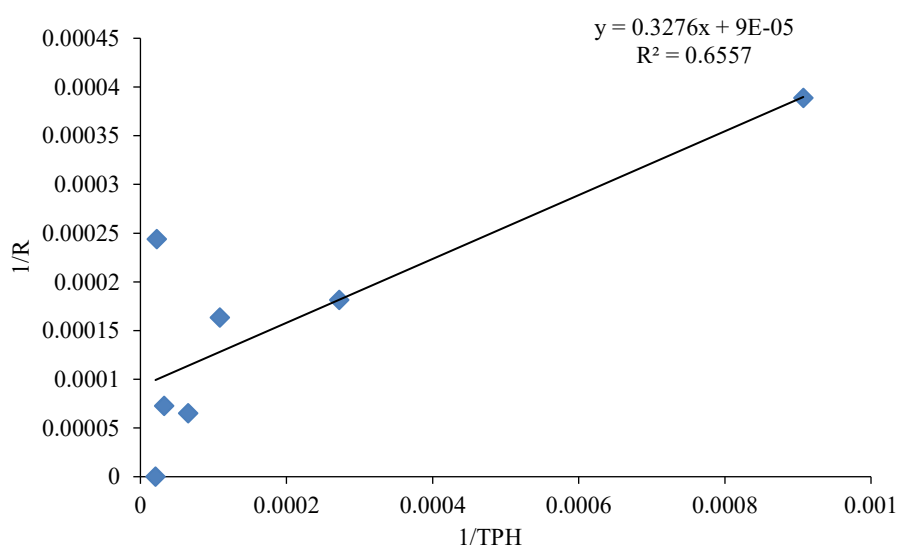


Figure 1. Reciprocal Rate ($\frac{1}{R}$) against Reciprocal of TPH ($\frac{1}{TPH}$) Degraded for Loamy Soil in Reactor A₂₀

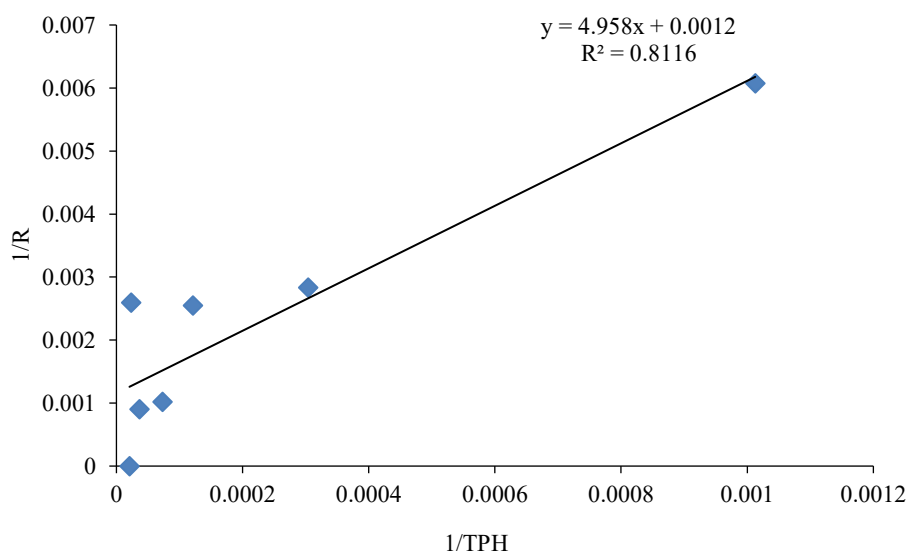


Figure 2. Reciprocal Rate ($\frac{1}{R}$) against Reciprocal of TPH ($\frac{1}{TPH}$) Degraded for Loamy Soil in Reactor A₄₀

Figure 2 established the line weaver bulk plot of reactor A₂₀ containing (40 g CPED). A plot of the inverse of the rate of degradation ($\frac{1}{R}$) against the reciprocal of the TPH degraded or substrate ($\frac{1}{S}$) is gives as linear equation of they = $4.968x + 0.0012$ with R^2 value of 0.8116 . The functional parameter of the line weaver bulk plot deduced from the linear graph were K_{TPH} and R_{max} . The value for R_{max} is evaluated as the $\frac{1}{R_{max}} = intercepts$, hence the R_{max} is give as the inverse of the intercept which is equal to 909.091, likewise the value of K_S for reactor A₄₀ (40 g CPEL) is evaluated $\frac{K_{TPH}}{R_{max}} = slope$, therefore $K_{TPH} = 4950.1ppm^{-1}$ and Figure 2 obeys the lineweaver Bulk plot.

Figure 3 established the line weaver bulk plot of reactor A₆₀ containing (60 g CPED). A plot of the inverse of the rate of degradation ($\frac{1}{R}$) against the reciprocal of the TPH degraded or substrate ($\frac{1}{TPH}$) is gives as linear equation of the form $y = 5.1252x + 0.0011$ with R^2 value of 0.8672. The functional parameter of the line weaver bulk plot deduced from the linear graph were K_S and R_{max} . The value for R_{max} is evaluated as the $\frac{1}{R_{max}} = intercepts$, hence the R_{max} is give as the inverse of the intercept which is equal to 909.091, likewise the value of K_S for reactor A₆₀ (60 g CPEL) is evaluated $\frac{K_{TPH}}{R_{max}} = slope$, therefore $K_{TPH} = 4950.1ppm^{-1}$.

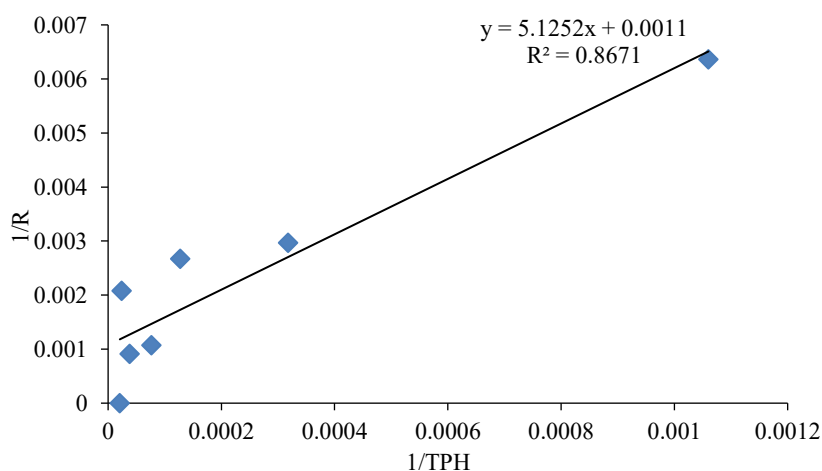


Figure 3. Reciprocal Rate ($\frac{1}{R}$) against Reciprocal of TPH ($\frac{1}{TPH}$) Degraded for Loamy Soil in Reactor A₆₀

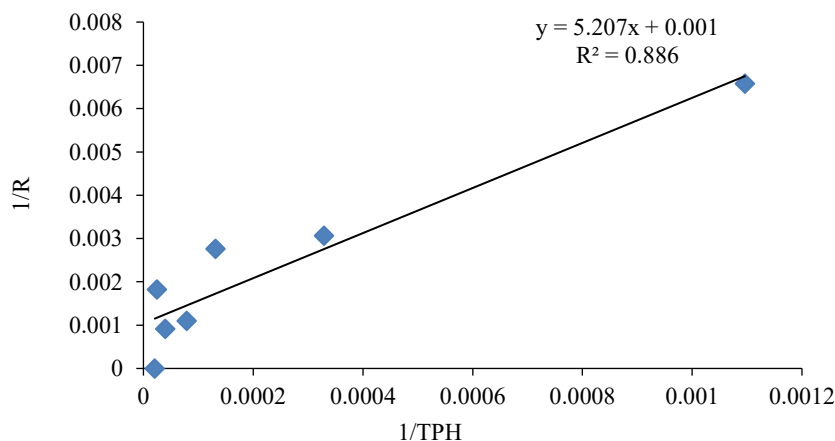


Figure 4. Reciprocal of Rate ($\frac{1}{R}$) against Reciprocal of TPH ($\frac{1}{TPH}$) Degraded for Loamy Soil in Reactor A₈₀

Figure 4 acknowledged the line weaver bulk plot of reactor A₂₀ containing (80 g CPED). A plot of the inverse of the rate of degradation ($\frac{1}{R}$) against the reciprocal of the TPH degraded or substrate ($\frac{1}{S}$) is gives as linear equation of the form $y = 5.207x + 0.001$ with R^2 value of 0.886. The functional parameter of the line weaver bulk plot inferred from the linear graph were K_S and R_{max} . The value for R_{max} is evaluated as the $\frac{1}{R_{max}} = intercepts$, hence the R_{max} is give as the inverse of the intercept which is equal to 909.091, similarly the value of K_S for reactor A₈₀ (60 g CPEL) is evaluated $\frac{K_{TPH}}{R_{max}} = slope$, therefore $K_{TPH} = 4950.1ppmd^{-1}$.

Figure 5 acknowledged the line weaver bulk plot of reactor A₁₀₀ containing (100 g CPED). A plot of the inverse of the rate of degradation ($\frac{1}{R}$) against the reciprocal of the TPH degraded or substrate ($\frac{1}{S}$) is gives as linear equation, $y = 5.3168x + 0.002$ with R^2 value of 0.9089. The functional parameters of the line weaver bulk plot inferred from the linear graph were K_S and R_{max} . The value for R_{max} is calculated as the $\frac{1}{R_{max}} = intercepts$, hence the R_{max} is give as the inverse of the intercept which is equal to 1000, similarly the value of K_S for reactor A₁₀₀ (100g CPEL) is evaluated $\frac{K_{TPH}}{R_{max}} = slope$, therefore $K_{TPH} = 5316.8ppm^{-1}$

Figure 6 demonstrate the line weaver bulk plot of reactor B₂₀ containing (20 g CPEL). A plot of the inverse of the rate of degradation ($\frac{1}{R}$) against the reciprocal of the TPH degraded or substrate ($\frac{1}{S}$) is gives as linear equation of the form $y = 0.2341x + 0.0001$ with R^2 value of 0.6655. The functional parameters of the line weaver bulk plot deduced from the linear graph were K_{TPH} and R_{max} . The value for R_{max} is evaluated as the $\frac{1}{R_{max}} = intercepts$, hence the R_{max} is give as the inverse of the intercept which is equal to 10000, likewise the value of K_S for reactor B₂₀ (20 g CPEL) is evaluated $\frac{K_{TPH}}{R_{max}} = slope$, therefore $K_{TPH} = 2341ppm^{-1}$

Figure 7 reveals that the line weaver bulk plot of reactor B containing (40 g CPEL) when a plot of the inverse of the rate of degradation ($\frac{1}{R}$) against the reciprocal of the TPH degraded or substrate ($\frac{1}{S}$) is gives as linear equation of the form $y = 3.5183x + 0.0013$ with R^2 value of 0.8416. The functional parameters of the line weaver bulk plot deduced from the linear graph were K_{TPH} and R_{max} . The value for R_{max} is evaluated as the $\frac{1}{R_{max}} = intercepts$, hence the R_{max} is give as the inverse of the intercept which is equal to 769.23, likewise the value of K_S for reactor B₄₀ (40g CPEL) evaluated $\frac{K_{TPH}}{R_{max}} = slope$, therefore $K_{TPH} = 2706.385ppm^{-1}$.

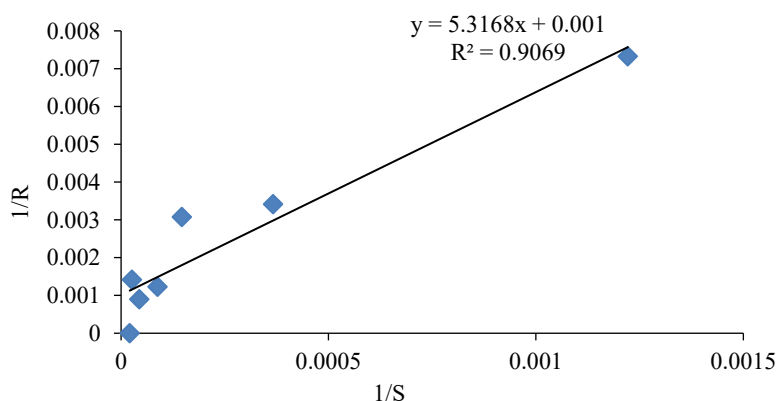


Figure 5. Reciprocal of Rate ($\frac{1}{R}$) of Biodegradation against Reciprocal of TPH($\frac{1}{TPH}$) Degraded for Loamy Soil in Reactor A₁₀₀

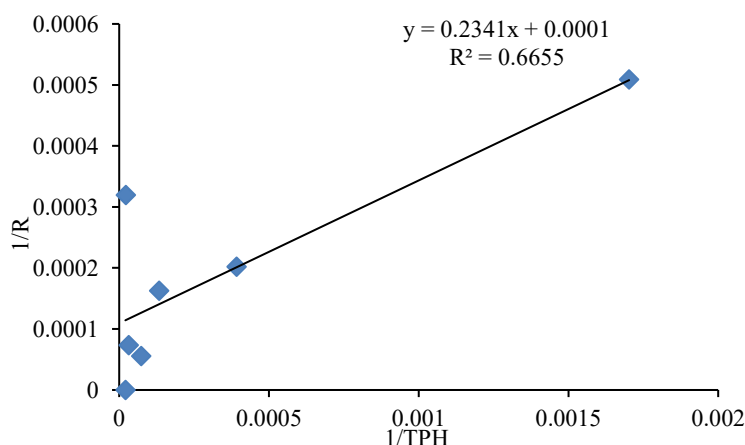


Figure 6. Reciprocal of Rate ($\frac{1}{R}$) of Biodegradation against Reciprocal of TPH ($\frac{1}{TPH}$) Degraded for loamy soil in Reactor B₂₀

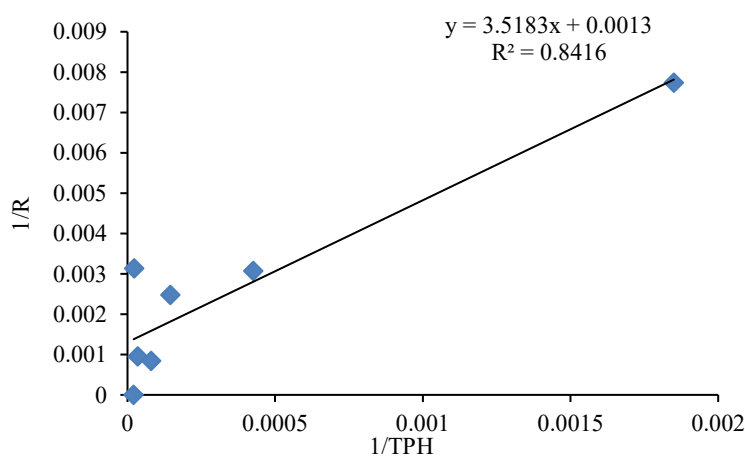


Figure 7. Reciprocal of Rate ($\frac{1}{R}$) against Reciprocal of TPH ($\frac{1}{TPH}$) Degraded for Loamy Soil in Reactor B

Figure 8 determine the line weaver bulk plot of reactor C enclosing (60g CPEL) with a plot of the inverse of the rate of degradation ($\frac{1}{R}$) against the reciprocal of the TPH degraded or substrate ($\frac{1}{S}$) is gives as linear equation of the form $y = 3.623x + 0.0012$ with R^2 value of 0.8931. The useful parameter of the line weaver bulk plot deduced from the linear graph were K_{TPH} and R_{max} . The value for R_{max} is evaluated as the $\frac{1}{R_{max}} = intercepts$, hence the R_{max} is give as the inverse of the intercept which is equal to 833.33, likewise the value of K_S for reactor B₆₀ (60 g CPEL) is evaluated $\frac{K_{TPH}}{R_{max}} = slope$, therefore $K_{TPH} = 3077.33ppm^{-1}$.

Figure 9 determine the line weaver bulk plot of reactor B₈₀ enclosing (80g CPEL) with a plot of the inverse of the rate of degradation ($\frac{1}{R}$) against the reciprocal of the TPH degraded or substrate ($\frac{1}{S}$) is gives as linear equation of the form $y = 3.69x + 0.0012$ with R^2 value of 0.91. The useful parameters of the line weaver bulk plot deduced from the linear graph were K_{TPH} and R_{max} . The value for R_{max} is evaluated as the $\frac{1}{R_{max}} = intercepts$, hence the R_{max} is give as the inverse of the intercept which is equal to 833.33, likewise the value of K_S for reactor B₈₀ (80 g CPEL) is evaluated $\frac{K_{TPH}}{R_{max}} = slope$, consequently $K_{TPH} = 3077.33ppm^{-1}$.

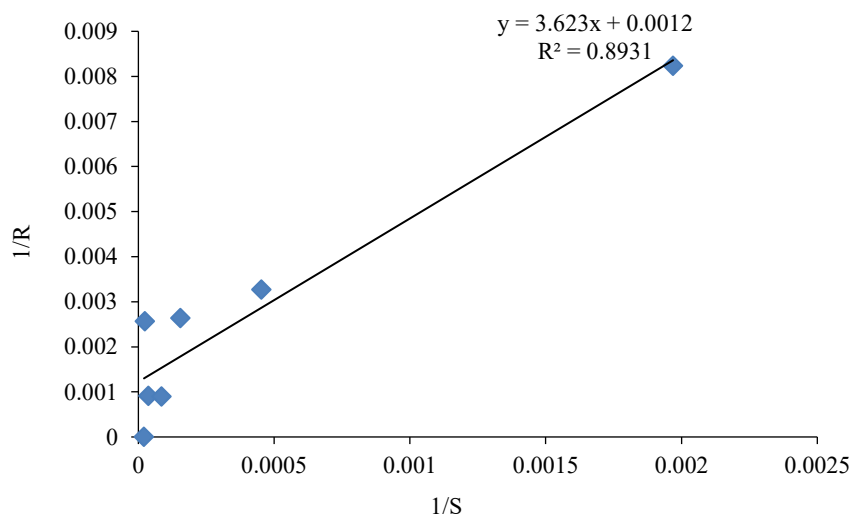


Figure 8. Reciprocal of Rate ($\frac{1}{R}$) of Biodegradation against Reciprocal of TPH ($\frac{1}{TPH}$) Degraded for Loamy Soil in Reactor C.

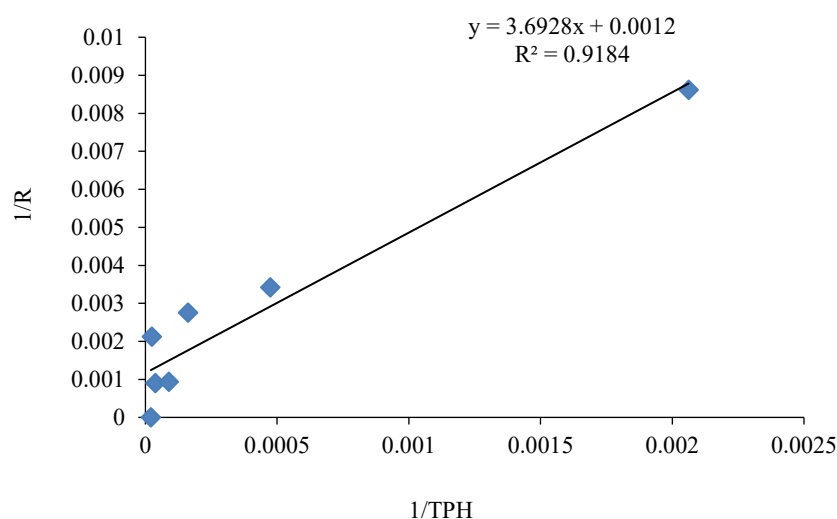


Figure 9. Reciprocal of Rate ($\frac{1}{R}$) against Reciprocal of TPH ($\frac{1}{TPH}$) Degraded for Loamy Soil in Reactor B₈₀

Figure 10 demonstrate the line weaver bulk plot of rector B₁₀₀ containing (100g CPEL). A plot of the inverse of the rate of degradation ($\frac{1}{R}$) against the reciprocal of the TPH degraded or substrate ($\frac{1}{S}$) is gives as linear equation of the form $y = 3.777x + 0.0012$ with R^2 value of 0.9332. The functional parameters of the line weaver bulk plot deduced from the linear graph were K_{TPH} and R_{max} . The value for R_{max} is evaluated as the $\frac{1}{R_{max}} = intercepts$, hence the R_{max} is give as the inverse of the intercept which is equal to 555.55, likewise the value of K_S for reactor B₁₀₀ (100 g CPEL) is evaluated $\frac{K_{TPH}}{R_{max}} = slope$, therefore $K_{TPH} = 3190.16ppm^{-1}$.

Figure 11 is a plot of reciprocal rate of biodegradation of substrate on sandy soil to the reciprocal of TPH degraded by the action of 20g of CPED label as reactor C₂₀. Figure 4.30 also demonstrate the line weaver bulk plot, upon which a linear equation of the form $y = 3.5457x + 0.0017$ was generated, from the plot in Figure 11it is deduced that R^2 value was found to be $R^2 = 0.8604$. the functional parameters

of the line weaver bulk plot given as K_{TPH} and R_{max} , these parameters can be evaluated from the relation $\frac{1}{R_{max}} = intercepts$ which upon evaluation gives the value of R_{max} for 20g CPED after treatment to be 588.2353. Also, the value of K_S for (20 g CPED) after treatment can be determine using the expression of $\frac{K_{TPH}}{R_{max}} = slope$, hence $K_{TPH} = 2085.706ppm^{-1}$. The result obtained is in agreement with that of Ukpaka [11]. This plot in Figure 11 obeys the Lineweaver Bulk Plot concept.

Figure 12 is a plot of reciprocal rate of biodegradation of substrate on sandy soil to the reciprocal of TPH degraded by the action of 40 g of CPED label as reactor C₄₀. Figure 12 also demonstrate the line weaver bulk plot, upon which a linear equation of the form $y = 3.5718x + 0.0017$ was generated, from the plot in Figure 12 it is deduced that R^2 value was found to be $R^2 = 0.8684$ the functional parameters of the line weaver bulk plot given as K_{TPH} and R_{max} , these parameters can be evaluated from the relation $\frac{1}{R_{max}} = intercepts$ which upon evaluation gives the value of R_{max} for 40 g CPED after treatment to be 587.2353. Also, the value of K_{TPH} for (40gCPED) after treatment can be determine using the expression of $\frac{K_{TPH}}{R_{max}} = slope$, hence $K_{TPH} = 2101.059ppm^{-1}$. The result obtained is in line with research carried by Ukpaka [11]. This plot in Figure 12 demonstrated the Lineweaver Bulk Plot concept.

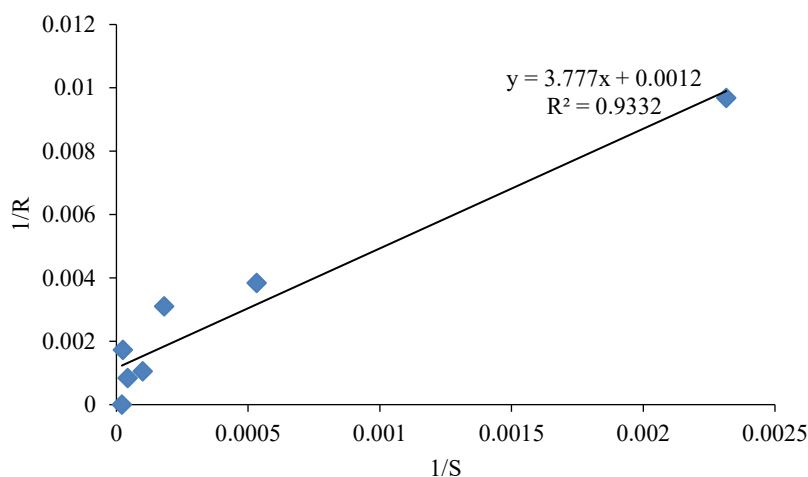


Figure 10. Reciprocal of Rate ($\frac{1}{R}$) against Reciprocal of TPH Degraded for loamy Soil in Reactor B₁₀₀

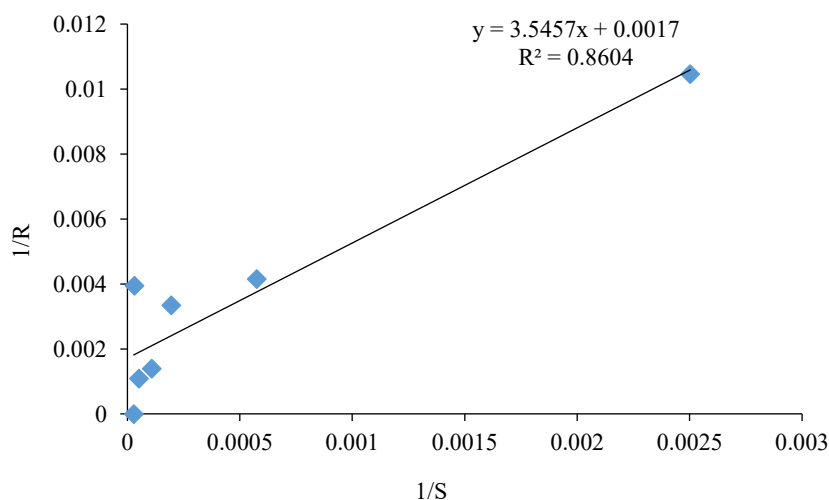


Figure 11. Reciprocal Rate ($\frac{1}{R}$) against Reciprocal of TPH Degraded for Sandy soil in Reactor C₂₀

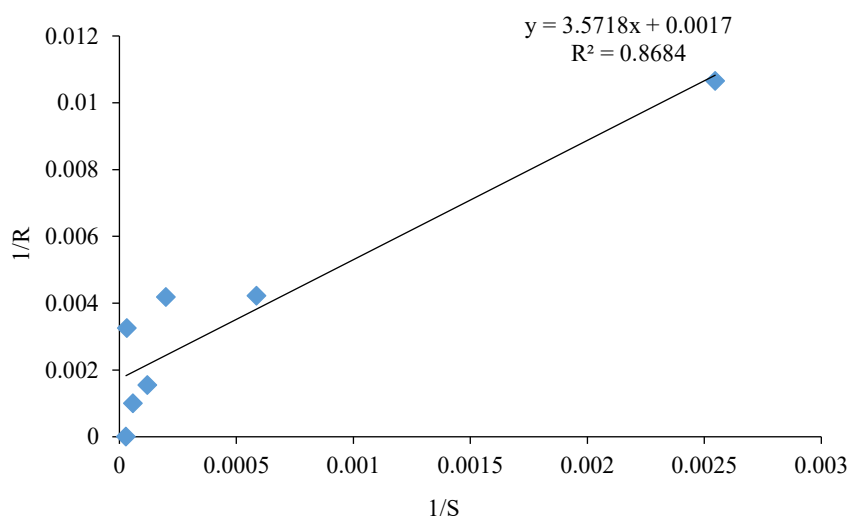


Figure 12. Reciprocal Rate ($\frac{1}{R}$) against Reciprocal of TPH Degraded for Sandy Soil in Reactor C_{40}

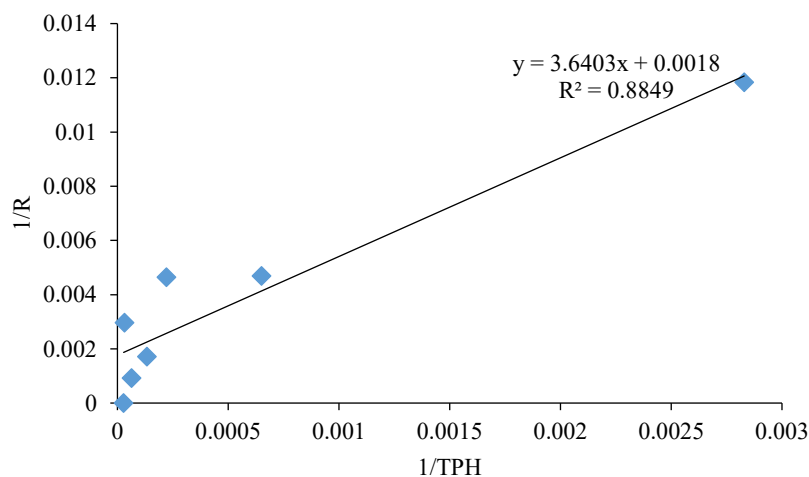


Figure 13. Reciprocal Rate ($\frac{1}{R}$) against Reciprocal of TPH Degraded for Sandy Soil in Reactor C_{60}

Figure 13 is a plot of reciprocal rate of biodegradation of substrate on sandy soil to the reciprocal of TPH degraded by the action of 60 g of CPED label as reactor C_{60} . Figure 13 also demonstrate the line weaver bulk plot, upon which a linear equation of the form $y = 3.6403 + 0.0018$, generated, from the plot in Figure 13 it is deduced that R^2 value was found to be $R^2 = 0.8849$ the functional parameters of the line weaver bulk plot given as K_{TPH} and R_{max} , these parameters can be evaluated from the relation $\frac{1}{R_{max}} = intercepts$ which upon evaluation gives the value of R_{max} for 60g CPED after treatment to be 587.2353. Also, the value of K_{TPH} for (60gCPED) after treatment can be determine using the expression of $\frac{K_{TPH}}{R_{max}} = slope$, hence $K_{TPH} = 2022.389 ppm^{-1}$ The result obtained is in line with research carried by Ukpaka [11]. This plot in Figure 13 demonstrated the Lineweaver Bulk Plot concept.

Figure 14 is a plot of reciprocal rate of biodegradation of substrate on sandy soil to the reciprocal of TPH degraded by the action of 80 g of CPED label as reactor C_{80} . Figure 14 also demonstrate the line weaver bulk plot, upon which a linear equation of the form $y = 3.78 + 0.0021$, generated, from the plot in Figure 14 it is deduced that R^2 value was found to be $R^2 = 0.8994$ the functional parameters of the line weaver bulk plot given as K_{TPH} and R_{max} , these parameters can be evaluated from the relation

$\frac{1}{R_{max}}$ = intercepts which upon evaluation gives the value of R_{max} for 80g CPED after treatment to be 476.1905. Also the value of K_S for (80 g CPED) after treatment can be determine using the expression of $\frac{K_{TPH}}{R_{max}}$ = slope, hence $K_{TPH} = 2022.389ppm^{-1}$ The result obtained is in line with research carried by Ukpaka [11]. This plot in Figure 14 demonstrated the line weaver Bulk plot concept.

Figure 15 is a plot of reciprocal rate of biodegradation of substrate in sandy soil to the reciprocal of TPH degraded by the action of 100 g of CPED label as reactor C_{100} . Figure 15 also demonstrate the line weaver bulk plot, upon which a linear equation of the form $y = 3.8394 + 0.0027$, generated, from the plot in Figure 15 it is deduced that R^2 value was found to be $R^2 = 0.8979$ the functional parameters of the line weaver bulk plot given as K_{TPH} and R_{max} , these parameters can be evaluated from the relation $\frac{1}{R_{max}}$ = intercepts which upon evaluation gives the value of R_{max} for 100g CPED after treatment to be 476.1905. Also the value of K_{TPH} for (100 g CPED) after treatment can be determine using the expression of $\frac{K_{TPH}}{R_{max}}$ = slope, hence $K_{TPH} = 2022.389ppm^{-1}$ The result obtained is in line with research carried by Ukpaka [11]. This plot in Figure 15 demonstrated the Lineweaver Bulk Plot concept.

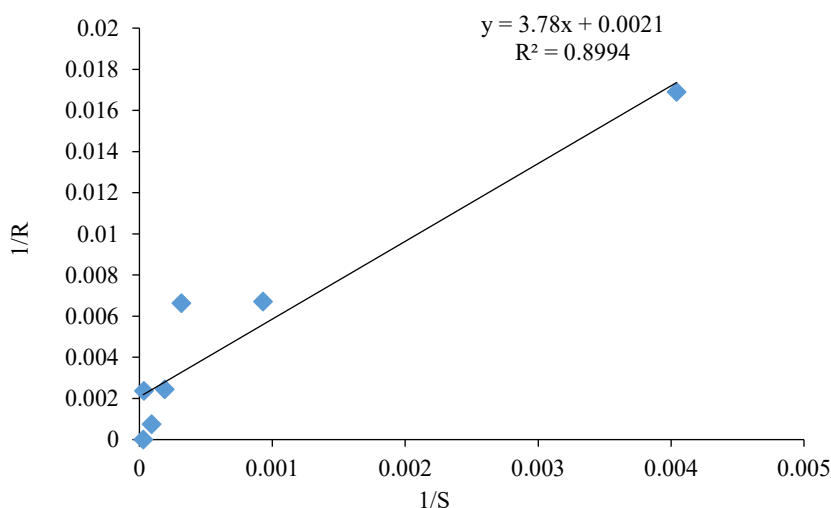


Figure 14. Reciprocal of Rate ($\frac{1}{R}$) against Reciprocal of TPH Degraded for Sandy Soil in Reactor C_{80}

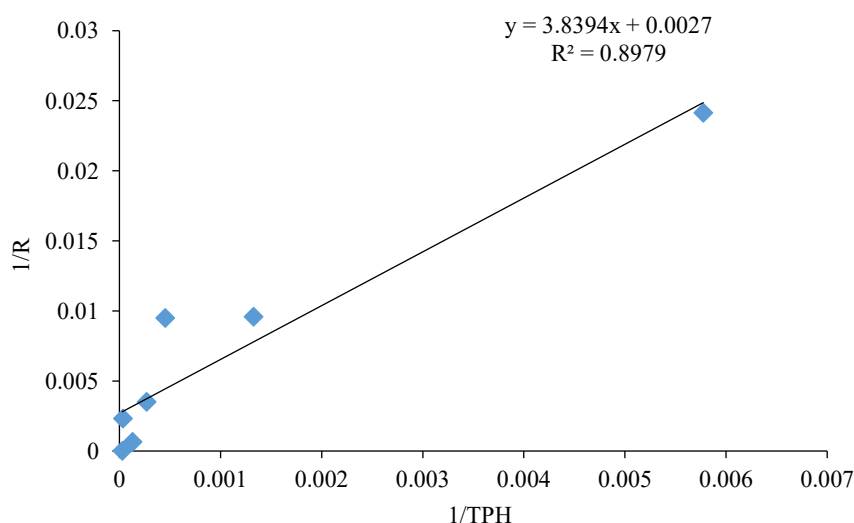


Figure 15. Reciprocal of Rate ($\frac{1}{R}$) against Reciprocal of TPH Degraded for Sandy Soil in Reactor C_{100}

Figure 16 demonstrate a plot of reciprocal rate of biodegradation of substrate in sandy soil to the reciprocal of TPH degraded on treatment of 20 g of CPEL label as reactor **D₂₀**. Figure 16 also illustrate the line weaver bulk plot, upon which a linear equation of the form $y = 3.2471x + 0.0019$ generated, from the plot in Figure 16 it is deduced that R^2 value was found to be $R^2 = 0.7857$, also the functional parameters of the line weaver bulk plot given as K_{TPH} and R_{max} , these parameters can be evaluated from the relation $\frac{1}{R_{max}} = intercepts$ which upon evaluation gives the value of R_{max} for 20g CPEL after treatment to be 526.3158. Also the value of K_{TPH} for (20gCPEL) after treatment can be determine using the expression of $\frac{K_{TPH}}{R_{max}} = slope$, hence $K_{TPH} = 1709ppm^{-1}$. The result obtained is in line with research carried by Ukpaka [11]. This plot in Figure 16 demonstrated the line weaver Bulk plot concept.

Figure 17 demonstrate a plot of reciprocal rate of biodegradation of substrate in sandy soil to the reciprocal of TPH degraded on treatment of 40 g of CPEL label as reactor **D₄₀**. Figure 17 also illustrate the line weaver bulk plot, upon which a linear equation of the form $y = 3.3804x + 0.0018$ generated, from the plot in Figure 17 it is deduced that R^2 value was found to be $R^2 = 0.7857$, also the functional parameters of the line weaver bulk plot given as K_{TPH} and R_{max} , these parameters can be evaluated from the relation $\frac{1}{R_{max}} = intercepts$ which upon evaluation gives the value of R_{max} for 40 g CPEL after treatment to be 555.576. Also, the value of K_S for (40 g CPEL) after treatment can be determine using the expression of $\frac{K_{TPH}}{R_{max}} = slope$, hence $K_{TPH} = 1878ppm^{-1}$. The result obtained is in line with research carried by Ukpaka [11]. This plot in Figure 17 demonstrates the Lineweaver Bulk Plot concept.

Figure 18 shows a plot of reciprocal rate of biodegradation of substrate in sandy soil to the reciprocal of substrate of TPH degraded on treatment of 60 g of CPEL label as reactor **D₆₀**. Figure 18 also illustrate the line weaver bulk plot, upon which a linear equation of the form $y = 3.3826x + 0.0018$ generated, from the plot in Figure 18 it is deduced that R^2 value was found to be $R^2 = 0.7857$, also the functional parameters of the line weaver bulk plot given as K_{TPH} and R_{max} , these parameters can be evaluated from the relation $\frac{1}{R_{max}} = intercepts$ which upon evaluation gives the value of R_{max} for 60 g CPEL after contacting with the substrate for 84days to be 555.5556. Also the value of K_{TPH} for (60 g CPEL) after treatment can be calculated using the expression of $\frac{K_{TPH}}{R_{max}} = slope$, hence $K_S = 1934.778ppm^{-1}$. The result obtained is in line with research carried by Ukpaka [11]. This plot in Figure 18 demonstrated the Lineweaver Bulk Plot concept.

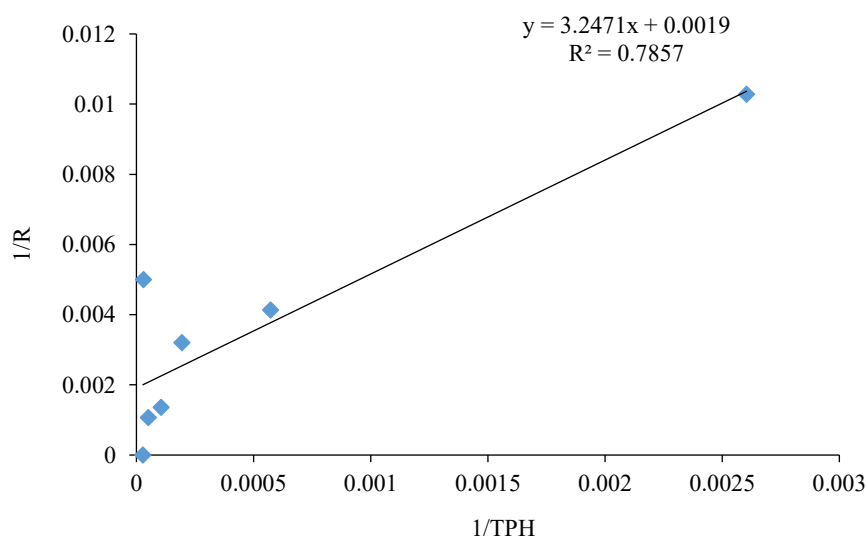


Figure 16. Reciprocal Rate ($\frac{1}{R}$) against Reciprocal of TPH Degraded for Sandy Soil in Reactor **D₂₀**

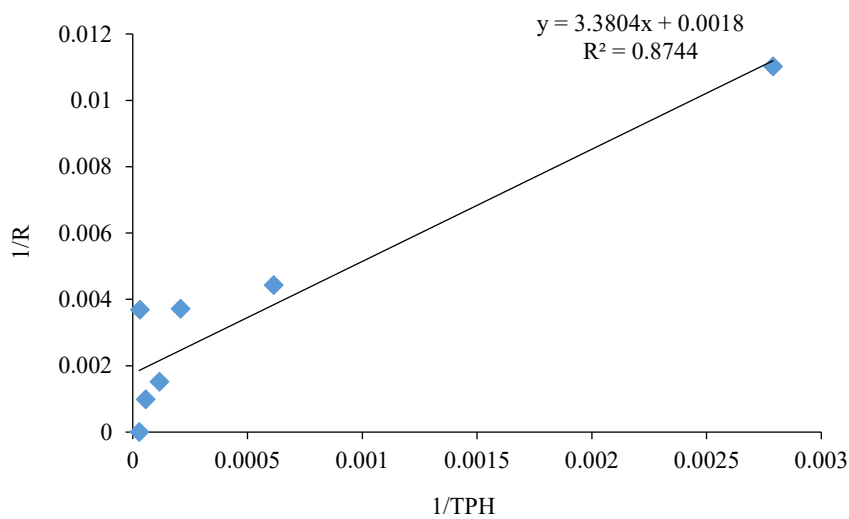


Figure 17. Reciprocal of Rate ($\frac{1}{R}$) against Reciprocal of TPH Degraded for Sandy soil in Reactor D₄₀

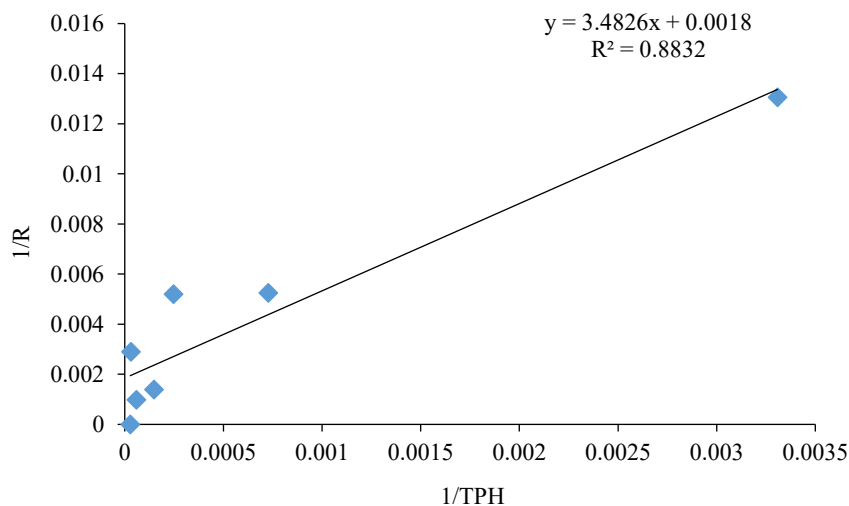


Figure 18. Reciprocal of Rate ($\frac{1}{R}$) against Reciprocal of TPH Degraded for Sandy Soil in Reactor D₆₀

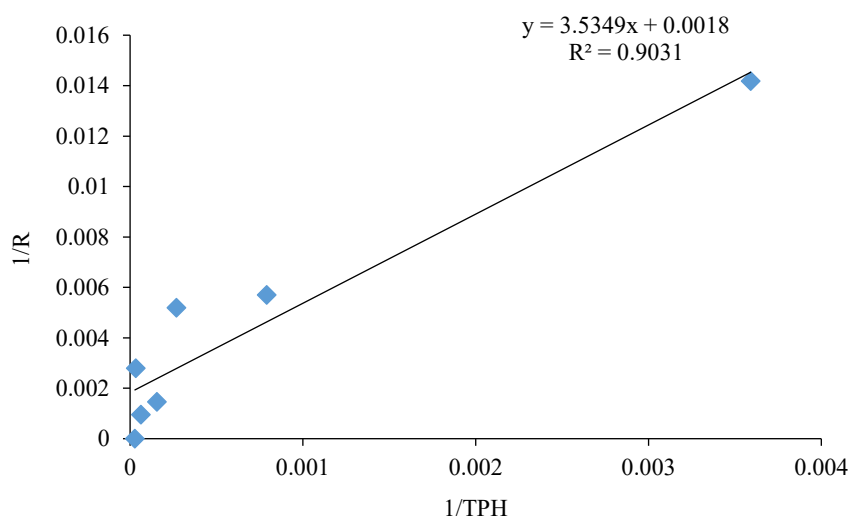


Figure 19. Reciprocal of Rate ($\frac{1}{R}$) against Reciprocal of TPH Degraded for Sandy soil in Reactor D₈₀

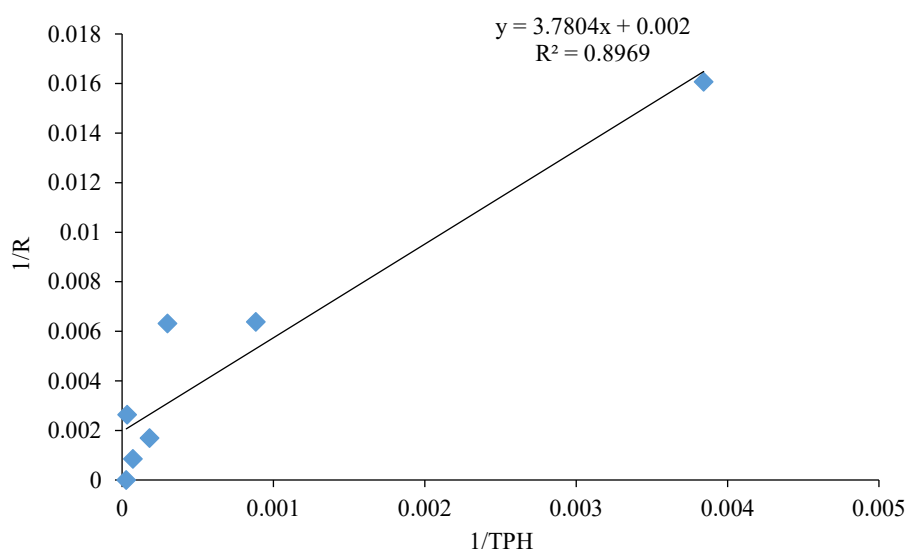


Figure 20. Reciprocal of Rate ($\frac{1}{R}$) against Reciprocal of TPH Degraded for Sandy Soil in Reactor D₁₀₀

Figure 19 shows a plot of reciprocal rate of biodegradation of substrate in sandy soil to the reciprocal of TPH degraded on treatment of 80 g of CPEL label as reactor D₈₀. Figure 19 also illustrate the line weaver bulk plot, upon which a linear equation of the form $y = 3.5349x + 0.0017$ generated, from the plot in Figure 19 it is deduced that R^2 value was found to be $R^2 = 0.7857$, also the functional parameters of the line weaver bulk plot given as K_{TPH} and R_{max} , these parameters can be evaluated from the relation $\frac{1}{R_{max}} = intercepts$ which upon evaluation gives the value of R_{max} for 80 g CPEL after contacting with the substrate for 84days to be 555.5566. Also the value of K_{TPH} for (80 g CPEL) after treatment can be calculated using the expression of $\frac{K_{TPH}}{R_{max}} = slope$, hence $K_{TPH} = 1963.733ppm^{-1}$. The result obtained is in line with research carried by Ukpaka [11]. This plot in Figure 19 demonstrated the Lineweaver Bulk Plot concept.

Figure 20 shows a plot of reciprocal rate of biodegradation of substrate in sandy soil to the reciprocal of TPH degraded on treatment of 100 g of CPEL label as reactor D₁₀₀. Figure 20 also illustrate the line weaver bulk plot, upon which a linear equation of the form $y = 3.7804x + 0.002$ generated, from the plot in Figure 4.39 it is deduced that R^2 value was found to be $R^2 = 0.8969$, also the functional parameters of the line weaver bulk plot given as K_{TPH} and R_{max} , these parameters can be evaluated from the relation $\frac{1}{R_{max}} = intercepts$ which upon evaluation gives the value of R_{max} for 100 g CPEL after contacting with the substrate for 84days to be 500.672. Also, the value of K_{TPH} for (100 g CPEL) after treatment can be calculated using the expression of $\frac{K_{TPH}}{R_{max}} = slope$, hence $K_{TPH} = 1890.2ppm^{-1}$. The result obtained is in line with research carried by Ukpaka [11]. This plot in Figure 20 demonstrates the Lineweaver Bulk Plot concept.

CONCLUSION

This research work was able to address the challenges caused by hydrocarbon contaminated soil environment, the mitigation of the highly concentrated hydrocarbon (TPH) was achieved by the application of bio-plant extract technology, therefore the use of Chaya plant extract had demonstrated high viability in remediating contaminated soil environment. The following conclusions were highlighted from the research such as: The research has demonstrated that the mass of biostimulant dosage influences biokinetic parameters. The Lineweaver-Burk Plot concept is instrumental in determining key parameters necessary for evaluating degradation rates and equilibrium constants. By computing the reciprocal of the velocity and plotting it against the reciprocal of the total petroleum

hydrocarbons, the Lineweaver-Burk Plot provides valuable insights into these processes. It was found that the rate of TPH degradation was controlled by the concentration of the biostimulant used. Overall, the biostimulant applied in this process has proven to be an effective remediant.

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