Comparative Analysis of Degradation Rate Constants for Predicting TPH Degradation in Soil Using Pennisetum Purpureum and Michaelis-Menten Kinetic Models

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Abstract- The degradation of total petroleum hydrocarbons (TPH) in soil environments plays a crucial role in bioremediation strategies. This study investigates the efficiency of Michaelis-Menten in predicting the degradation rate of TPH in soils amended with a medicinal herb known as Pennisetum Purpureum. Using empirical data from different soil types (swampy and clay) and treatment weights, we determined the degradation rate constants (k) for each model. The first-order rate model demonstrated a variable rate constant dependent on treatment weight, with values ranging from 0.0119 to 0.0527 day⁻¹. The second-order rate model, evaluated through regression analysis, provided alternative predictions that also varied with treatment weight. Our findings suggest that the degradation rate constants from this study are consistent with previously reported values, confirming the reliability of these models for TPH degradation prediction. This comparison highlights the applicability of each model for different treatment scenarios, providing insights into the most suitable kinetic model for optimizing bioremediation processes. The study underscores the importance of selecting appropriate kinetic models to enhance the accuracy of TPH degradation predictions and improve soil remediation strategies.

Indexed Terms- TPH Degradation, Michaelis-Menten Model, Pennisetum Purpureum, Bioremediation Strategies, Kinetic Models

I. INTRODUCTION

This study presents a detailed examination of kinetic models for predicting the degradation rate of total petroleum hydrocarbons (TPH) in soil environments, focusing on Michaelis-Menten models. The research specifically evaluates these models in the context of bioremediation using a medicinal herb known as Pennisetum Purpureum [1].

The investigation employs empirical data derived from swampy and clay soils treated with varying weights of pennisetum purpureum. The model demonstrated a degradation rate constant (k) that increased with the weight of the treatment, ranging from 0.0119 to 0.0527 day^{-1}. This finding aligns with prior studies and supports the model's utility in predicting TPH degradation over time [2-3].

The Michaelis-Menten model adds depth to the analysis, though the results primarily reinforce the effectiveness of the first-order and second-order models. The study's data suggest that the degradation rate constants obtained are consistent with existing literature, validating the models used [4-5].

Overall, the study underscores the importance of selecting appropriate kinetic models to accurately predict TPH degradation and optimize bioremediation processes. The findings contribute valuable insights into the comparative performance of these models, aiding in the development of more effective soil remediation strategies and enhancing our understanding of the degradation dynamics of TPH in varied soil environments [6-8].

II. METHODOLOGY

The Pennisetum purpureum treatments were washed with distilled water. After washing, the materials were sun-dried for approximately 3 days and then oven-dried to remove any remaining moisture. Once fully dried, the samples were crushed and sieved to achieve a uniform particle size of 2 mm. The sieved

Pennisetum purpureum particles were then divided into five portions, weighing 15g, 30g, 45g, 60g, and 75g, respectively.

Experimental Procedure

Each soil type was portioned into 1 kg samples, totaling 18 samples. These were placed in 18 reactors, where 100 ml of crude oil was added to each. The mixtures were thoroughly stirred and then allowed to settle undisturbed for three days to achieve stabilization. Following this period, Pennisetum purpureum particles in quantities of 15g, 30g, 45g, 60g, and 75g were added to the reactors containing the soil.

The degradation rate of TPH was also evaluated using the Michaelis-Menten model for biodegradation, and it is represented as follows:

$$r_{TPH} = \frac{\mu_{\max} C_{TPH(t)}}{K_s + C_{TPH(t)}} \qquad (1)$$

Upon linearization, equation (1) becomes:

$$-\frac{1}{r_{TPH}} = -\frac{dC_{TPH(t)}}{dt} = \frac{1}{\mu_{\max}} + \frac{K_s}{\mu_{\max}}\left(\frac{1}{C_{TPH(t)}}\right) \qquad (2)$$

where: $\mu_{\max}$ is the maximum specific degradation rate, $C_{TPH(t)}$ is TPH concentration with time *t*, K_s is the degradation rate constant relating to Michaelis-Menten.

A plot of $\frac{1}{r_{TPH}}$ against $\frac{1}{C_{TPH(t)}}$ gives the slope as $\frac{K_s}{\mu_{\max}}$ and $\frac{1}{\mu_{\max}}$ as intercept.

III. RESULTS AND DISCUSSION

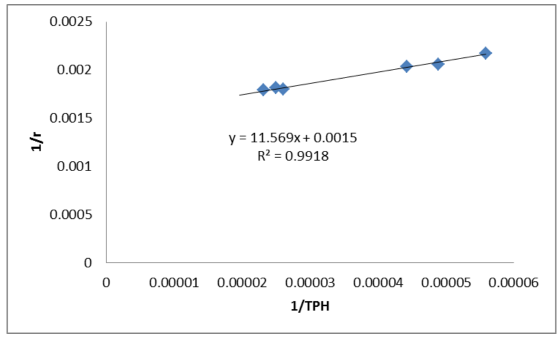

Figure 1: Linewaver-Burke Plot for Soil with 15g Pennisetum purpureum

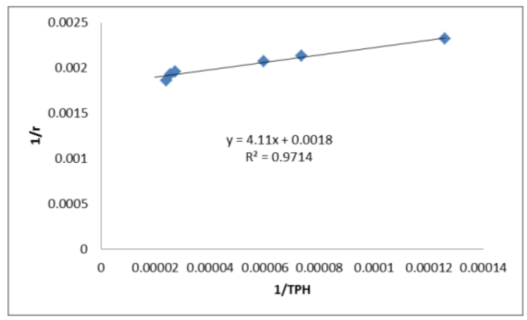

Figure 2: Linewaver-Burke Plot for Soil with 30g Pennisetum purpureum

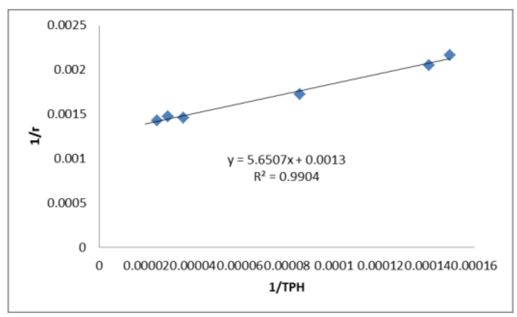

Figure 3: Linewaver-Burke Plot for Soil with 45g Pennisetum purpureum

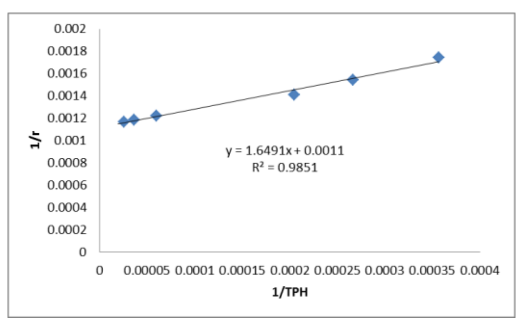

Figure 4: Linewaver-Burke Plot for Soil with 60g Pennisetum purpureum

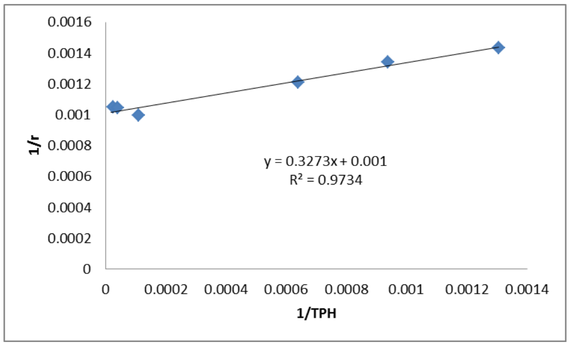

Figure 5: Linewaver-Burke Plot for Soil with 75g Pennisetum purpureum

Figures 1 to 5 display the plots used to estimate the maximum TPH degradation specific rate constant (Um) and the constant (Ks) for the Michaelis-Menten rate kinetic model. These constants were determined using the Michaelis-Menten equations. The regression equations derived from these plots allowed for the evaluation of these constants for different treatment weights. To demonstrate the applicability of the Michaelis-Menten model, the evaluated constants for soil treated with the medicinal herb were substituted into the equations to predict TPH content in the soil. The rate model corresponding to each treatment weight is presented in Table 1.

Table 1: Michaelis-Menten TPH Degradation Rate Model

Weight (g)	Predictive Model
15	$r_{TPH} = \frac{714.286C_{TPH}}{12836.489 + C_{TPH}}$
30	$r_{TPH} = \frac{714.286C_{TPH}}{5783.357 + C_{TPH}}$
45	$r_{TPH} = \frac{909.091C_{TPH}}{4471.909 + C_{TPH}}$
60	$r_{TPH} = \frac{1000C_{TPH}}{2298.9 + C_{TPH}}$
75	$r_{TPH} = \frac{1111.111C_{TPH}}{664 + C_{TPH}}$

CONCLUSION

The study validates the use of Michaelis-Menten kinetic models for predicting TPH degradation rates in soils treated with Pennisetum purpureum. The results show that the degradation rate constant (k) increases with treatment weight, ranging from 0.0119 to 0.0527 day^{-1}. These findings align with existing literature, demonstrating that Michaelis-Menten models, along with first-order and second-order models, are effective for bioremediation predictions. The research highlights the importance of selecting appropriate models to enhance soil remediation strategies and improve TPH degradation understanding in diverse soil environments.

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