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Research article

MODEL ANALYSIS TO MONITOR STATIONARY PHASE OF THERMOTOLERANT DEPOSITION IN LATERITIC AND SILTY FORMATION AT MGBUOBA DISTRICT OF PORT HARCOURT, NIGER DELTA OF NIGERIA

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Abstract

Model analysis to examine stationary phase of thermotolerant in the study area has been thoroughly expressed. The concept of this study is to critically evaluate the developed model equations that can definitely monitor and predict the rate of deposition and migration of thermotolerant in the study area. The expressed theoretical values from both predictive and validated were compared to critically assessed there rate efficiency in monitoring and evaluation of thermotolerant deposition and migration in the study area, the study shows that both theoretical parameters and there expressed model equation can be applied for predicting the deposition and migration level thermotolerant in the study location, the model is imperative because it will assist experts in the field in different dimension in monitoring and evaluation of thermotolerant in the study area.

Keywords: model analysis, stationary phase, thermotolerant deposition, lateritic and silty formation

1. Introduction

Grain size, shape, and packing are characteristics of granular porous media that have a significant effect on groundwater flow, affecting both porosity and permeability. Hubbert [1940] determined that if uniform spheres are uniformly packed, porosity is not a function of grain diameter but permeability is a function of the square of the grain diameter. However, natural sediment does not consist of uniform grains and packing; it contains mixtures of finer and coarse grains of irregular shapes and complex packing arrangements. Nevertheless, the effects on porosity and permeability when sediment is not uniform in size and packing have been extensively explored but the effects on porosity and permeability when sediment is not uniform in shape needs to be explored further. Laboratory and field experiments have verified that grain size and packing affect porosity and permeability in unconsolidated clastic sediment [Freeze and Cherry, 1979; marsily, 1986; Domenico and Schwartz, 1990,Eluozo, 2013]. Research has also been conducted on estimating hydraulic parameters, porosity and permeability, and the sediment parameters, grain size and packing. Koltermann and Gorelick [1995] worked to improve the knowledge of these relationships by modifying previous petrophysical models to more accurately predict the permeability of sediment mixtures. Kamann [2004] expanded on the work of Koltermann and Gorelick [1995] to account for five possible types of packing rather than the two types of packing upon which their fractional packing model was based. He took porosity and permeability

Measurements on model bimodal sediment mixtures that varied in the volume fraction of finer grains, which he compared with predicted values. In keeping with Koltermann and Gorelick [1995], Kamann [2004] also modeled the porosity and permeability of bimodal sediment mixtures to address the effect of the volume fraction of fines. As the volume fraction of fines increases within a sediment mixture, porosity changes as the packing of the mixture changes. A porosity minimum occurs when the volume of the finer component equals the pore volume of the coarser component. Kamann.s [2004] used spherical grains to model poorly-sorted sands and sandy gravels. Spherical glass beads and marbles were used to represent fine sand, medium sand, coarse sand and pebble grain sizes. Kamann [2004] chose to use spherical grains to eliminate variations in shape. He assumed that the bimodal sediment mixtures of spherical glass beads and marbles provided an approximation of natural sediment. Conrad [2006] focused specifically on measurements taken at small support scales using the air-based method of determining permeability on mixtures of spherical grains. He revised the permeability procedures, improved the air-based permeameter correction model developed by Kamann [2004], replicated and improved upon the permeability measurements taken by Kamann [2004], and further confirmed the applicability of the petrophysical model for permeability. The research conducted by Koltermann and Gorelick [1995], Kamann [2004] and Conrad [2006] explored the effect of grain size and packing on porosity and permeability. The focus of this research will explore the effect of grain size, shape, and packing on porosity and permeability by using bimodal mixtures of natural sediment This study will continue the work of Kamann [2004] and Conrad [2006] by replacing spherical glass beads and marbles with natural sand grains and pebbles to reexamine the effect of the volume fraction of fines on porosity and permeability. The goals of this study are to (1) measure porosity and permeability for mixtures of natural sediment that vary by percentages of the volume fraction of finer grains, (2) to evaluate if the model created by Kamann [2004] based on spherical grains is accurate for natural sediment grains and (3) to improve the confidence of estimating porosity and permeability [Peter 2005, Eluozo, 2013].

Soil and groundwater contamination remains a threat to public health and the environment despite decades of research. Numerous remediation technologies including bioremediation, thermal treatment, soil vapor extraction (SVE), zero-valent iron (ZVI), and in situ chemical oxidation (ISCO) have been developed over the past 30 years.

Bioremediation is a cost-effective and simple remediation process for the degradation of contaminants such as benzene, toluene, ethylbenzene, and xylenes (BTEX) [Kao et al., 2010; Nebe et al., 2009]. However, bioremediation is constrained by the available microbial community and by its degradation capacity in a given environment [Steliga et al., 2009]. Due to the complexities of extending laboratory results to the field [Stenuit et al., 2008], the actual rate of degradation as a result of bioremediation is slow relative to other treatments and often relies on natural attenuation, where no treatment is applied and the contaminant degrades naturally (Kao et al., 2010). Bioremediation, SVE, and ZVI degrade or constrain a narrow range of contaminants and are generally unable to treat sorbed contaminants and dense Nonaqueous phase liquids (DNAPLs) due to mass transfer limitations [Watts and Teel, 2006; Watts, 1998]. Persulfate is typically activated to promote contaminant degradation (Liang et al., 2004; aldemer et al., 2007; Furman et al., 2009). The activating agents include: iron-cheated activation [Liang et al., 2004], base activation [Furman et al., 2009], and organic activation [Ahmad, 2010,Eluozo 2013].

2. Materials and method

Soil samples from several different boring locations, were collected at intervals of three metres each (3m). Soil sample were collected in three different location, applying insitu method of sample collection, the soil sample were collect for analysis, standard laboratory analysis were collected to determine the thermotolerant concentration through column experiment, the result were analysed to determine the influence on thermotolerant transport between lateritic and silty soil formation in the study area.

3. Predictive governing equation

Nomenclature

K_n = Coefficient of inhibition [MTL^{-3}]

K_d = Half Concentration of substrate under Aerobic Respiration [MTL^{-3}]

C = Concentration of Thermotolerant [MTL^{-3}]

T = Time [T]

X, y = Distance [L]

$$K_d \frac{\partial^2 c_5}{\partial y^2} = K_n \frac{\partial c_5}{\partial x} \quad \text{.............} \quad (1)$$

Let $C_5 = YX$

$$\frac{\partial c_5}{\partial y} = Y^{11} X \quad \text{..............................} \quad (2)$$

$$\frac{\partial c}{\partial x} = X^1 Y \qquad \text{.............................. (3)}$$

$$K_d Y^{11} X = -K_n X^1 Y \qquad \text{.............................. (4)}$$

$$K_d \frac{Y^{11}}{Y} = -K_n \frac{X^1}{X} \qquad \text{.............................. (5)}$$

$$K_d Y^{11} X = -K_n X^1 Y = -\beta^2 \qquad \text{.............................. (6)}$$

Let $K_d \frac{Y^{11}}{Y} = -K_n \frac{X^1}{X} = \beta^2$ .... (7)

$$K_d Y^{11} = -\beta^2 \qquad \text{.............................. (8)}$$

$$Y^{11} + \frac{\beta^2}{K_d} = 0 \qquad \text{.............................. (9)}$$

Auxiliary equation

$$M^2 + \frac{\beta^2}{K_d} = 0 \qquad \text{.............................. (10)}$$

$$M = \pm i \frac{\beta}{\sqrt{K_d}} \qquad \text{.............................. (11)}$$

$$\therefore Y = A Cos \frac{\beta}{\sqrt{K_d}} y + B Sin \frac{\beta}{\sqrt{K_d}} y \qquad \text{.............................. (12)}$$

$$K_n \frac{X^{11}}{X} = +\beta^2$$

$$\int \frac{dx}{x} = \int \frac{+\beta}{K_n} dx \qquad \text{.............................. (13)}$$

$$LnX = \frac{+\beta^2}{K_n} x + a_6 \qquad \text{.............................. (14)}$$

$$X = C\ell^{\frac{+\beta}{K_n}x} \quad \text{..............................} (15)$$

$$C_5 = C\ell^{\frac{+\beta^2}{K_n}t}\left(A\,Cos\frac{\beta}{\sqrt{K_d}}y + B\,Sin\frac{\beta}{\sqrt{K_d}}y\right) \quad \text{..............................} (16)$$

3. Validated Theoretical Equation

Theoretical background for 3rd degree polynomial curve fitting

General: $y = a_0 + a_1x + a_2x^2 + a_3x^3 + ...+ a_nx^n$

If the above polynomial fits the pair of data (x, y) it means that every pair of data will satisfy the equation (polynomial).

Thus; $y_1 = a_0 + a_1x_1 + a_2x_1^2 + a_3x_1^3 + ...+ a_nx_1^n$ .... (1)

$y_2 = a_0 + a_1x_2 + a_2x_2^2 + a_3x_2^2 + ...+ a_nx_2^n \ldots$ .... (2)

$y_3 = a_0 + a_1x_3 + a_2x_3^2 + a_3x_2^2 + ...+ a_nx_2^n$ .... (3)

$y_4 = a_0 + a_1x_4 + a_2x_n^2 + a_3x_n^2 + ...+ a_nx_4^n$ .... (4)

Summing all the equations will yield (1 n) $\rightarrow$

$$\sum_{i=1}^{i=n} y_i = \sum a_0 + \sum_{i=1}^{i=n} a_1\, x_i + \sum_{i=1}^{i=n} a_2x_i^2 + \sum_{i=1}^{i=n} a_3x_i^3 + \sum_{i=1}^{i=n} a_4x_i^4 + ...+ \sum_{i=1}^{i=n} a_nx_i^n$$

$$\boxed{\sum_{i=1}^{i=n} y_i = na_0 + a_1\sum_{i=1}^{n} x_i + a_2\sum_{i=1}^{n} x_i^2 + a_3\sum_{i=1}^{n} x_i^3 + ...+ \sum_{i=1}^{n} x_i^n} \quad \text{..........} (5)$$

To form the equations to solve for the constants $a_0,\ a_1,\ a_2, a_3,\ ....a_n$.

We multiply equations (3.84) by $x_{i,}\ x_i^2,\ x_i^3 ....\ x_i^n$.

$$\sum_{i=1}^{1} y_i = na_0 + a_1 \sum x_i + a_2 \sum x_i^2 + a_3 \sum x_i^3 + ... + a_n \sum x_i^n \quad .... \quad (6)$$

Multiply equation (6) by x_i

$$x_i \sum y_i = na_0 \, x_i + a_1 \, x_i \sum x_i + a_2 \, x_i \sum x_i^2 + a_3 \, x_i \sum x_1^3 + ... + a_n \, x_i \sum x_i^n$$

$$\sum y_i \, x_i = a_0 \sum x_i + a_1 \sum x_i^2 + a_2 \sum x_i^3 + a_3 \sum x_i^4 + ... + a_n \sum x_i^{n+1} \quad .... \quad (7)$$

Multiply equation (6) by x_i^2

$$x_i^2 \sum y_i = na_0 \, x_i^2 + a_1 \, x_i^2 \sum x_i + a_2 \, x_i^2 \sum x_i^2 + a_3 \, x_i^2 \sum x_i^3 + ... + a_n \, x_i^2 \sum x_i^n \quad .. \quad (8)$$

$$\sum y_i \, x_i^2 = a_0 \sum x_i^2 + a_1 \sum x_i^3 + a_2 \sum x_i^4 + a_3 \sum x_i^5 + ... + a_n \sum x_i^{n+2} \quad .... \quad (9)$$

Multiply equation (3.85) by x_i^3

$$x_i^3 \sum y_i = na_0 \, x_i^3 + a_1 \, x_i^3 \sum x_i + a_2 \, x_i^3 \sum x_i^2 + a_3 \, x_i^3 \sum x_i^3 + ... + a_n \, x_i^3 \sum x_i^n$$

$$\sum y_i \, x_i^3 = a_0 \sum x_i^3 + a_1 \sum x_i^4 + a_2 \sum x_i^5 + a_3 \sum x_i^6 + ... + a_n \sum x_i^{n+3} \quad .... \quad (10)$$

Multiply equation (6) by x_i^n

$$x_i^n \sum y_i = a_0 n \, x_i^n + a_1 \, x_i^n \sum x_i + a_2 \, x_i^n \sum x_i^2 + a_3 \, x_i^n \sum x_i^3 + ... + a_n \, x_i^n \sum x_i^n$$

$$= a_0 \sum x_i^n + a_1 \sum x_i^{n+1} + a_2 \sum x_i^{n+2} + a_3 \sum x_i^{n+3} + ... + a_n \sum x_i^{n+n} \quad .... \quad n$$

Putting equation (6) to n into matrix form

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$$\begin{bmatrix} n & \sum x_i & \sum x_i^2 & \sum x_i^3 & \ldots\ldots \sum x_i^n \\ \sum x_i & \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \ldots\ldots \sum x_i^{n+1} \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \ldots\ldots \sum x_i^{n+2} \\ \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \sum x_i^6 & \ldots\ldots \sum x_i^{n+3} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \sum x_i^n & \sum x_i^{n+1} & \sum x_i^{n+2} & \sum x_i^{n+3} & \ldots\ldots \sum x_i^{n+n} \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \\ \ldots\ldots \\ a_n \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum y_i x_i \\ \sum y_i x_i^2 \\ \sum y_i x_i^3 \\ \ldots \\ \sum y_i x_i^n \end{bmatrix}$$

Solving the matrix equation yields values for constants $a_0,\ a_1,\ a_2, a_3, \ldots\ldots a_n$ as the case may be depending on the power of the polynomial. From the above matrix; for our particular case; i.e. polynomial of the third order:

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 \tag{11}$$

The equivalent matrix equation will be; ($n = 3$).

$$\begin{bmatrix} n & \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \sum x_i^5 \\ \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \sum x_i^6 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum y_i x_i \\ \sum y_i x_i^2 \\ \sum y_i x_i^3 \end{bmatrix}$$

Table 1: Comparison of Predictive and Validated Theoretical Values of Thermotolerant at Different Depths

Depths [m]	Predictive Theoretical Values	Validated Theoretical Values
3	-0.14	0.18
6	2.07	3.48
9	5.22	7.14
12	9.3	11.37
15	14.32	16.51
18	20.28	22.87
21	27.18	30.78
24	35.01	40.56
27	43.77	52.53
30	53.48	67.03

Table 2: Comparison of Predictive and Validated Theoretical Values of Thermotolerant at Different Depths

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Depths [m]	Predictive Theoretical Values	Validated Theoretical Values
3	0.92	0.98
6	0.94	0.91
9	1.09	1.08
12	1.36	1.39
15	1.76	1.82
18	2.29	2.37
21	2.94	3.1
24	3.71	3.85
27	4.62	4.79
30	5.65	5.85

Table 2: Comparison of Predictive and Validated Theoretical Values of Thermotolerant at Different Depths

Depths [m]	Predictive Theoretical Values	Validated Theoretical Values
3	1.64	1.18
6	3.22	3.48
9	6.2	7.14
12	10.58	11.37
15	16.37	16.51
18	23.56	22.87
21	32.15	30.78
24	42.15	40.56
27	57.98	52.53
30	66.36	67.03

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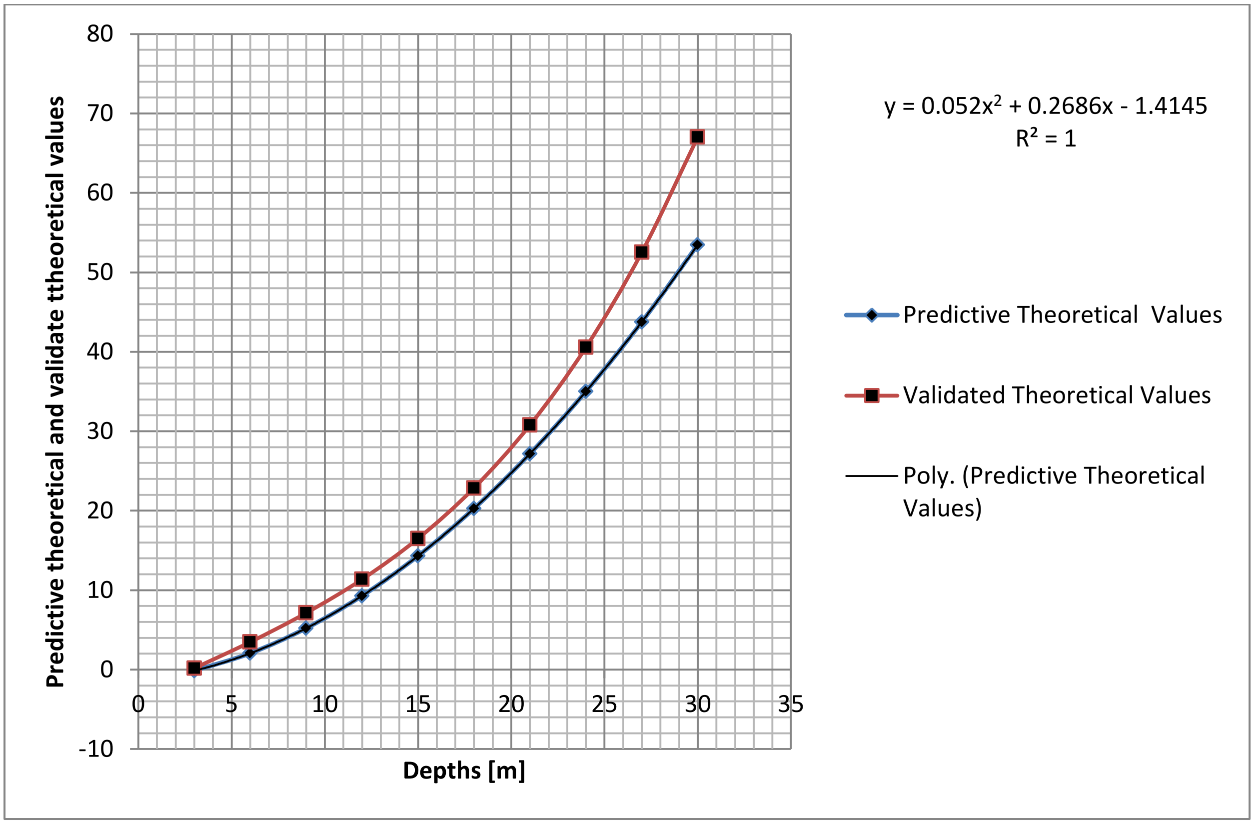

Figure 1: Comparison of Predictive and Validated Theoretical Values of Thermotolerant at Different Depths

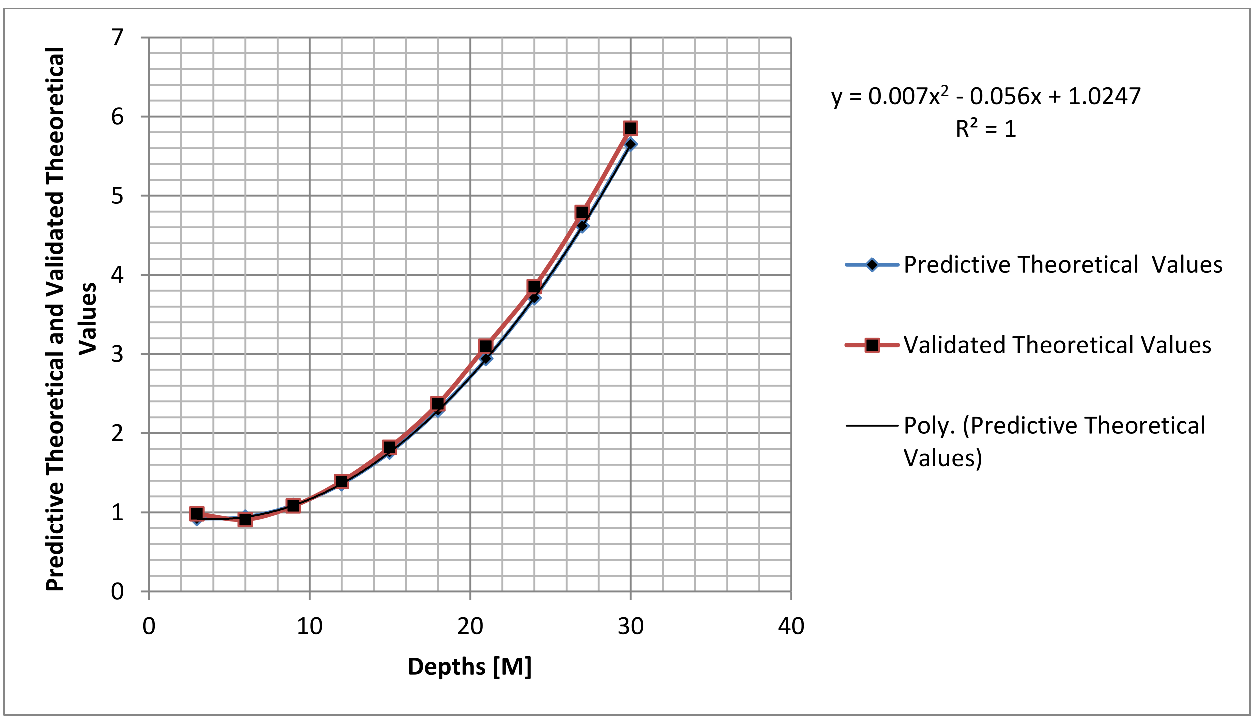

Figure 2: Comparison of Predictive and Validated Theoretical Values of Thermotolerant at Different Depths

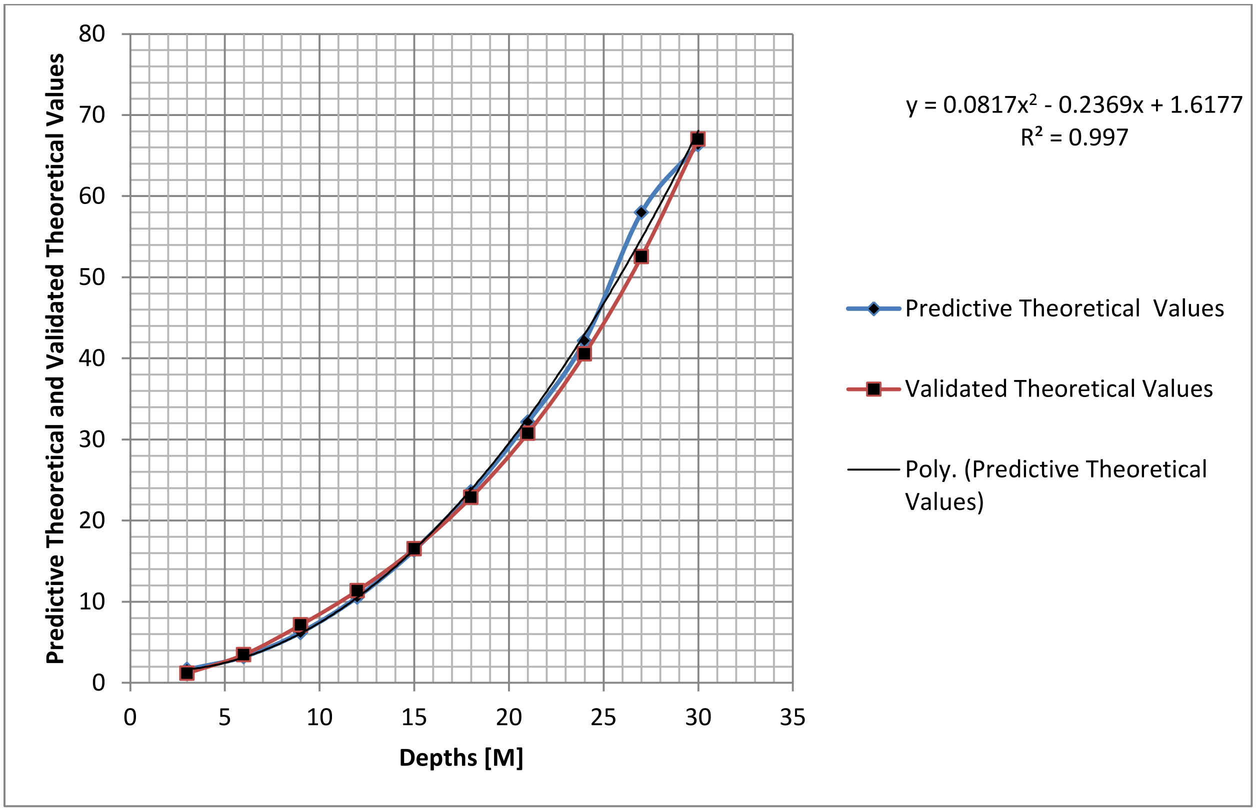

Table 3: Comparison of Predictive and Validated Theoretical Values of Thermotolerant at Different Depths

The expression from figure one [1-3] shows how thermotolerant behave in stationary phase, the predictive theoretical values express its deposition in exponential phase, similar condition were found on the validated theoretical values, it migrated in rapid level, these are base on the conditions of stationary phase , because the microbes found to station on some particular region of the formation, this condition increase the deposition of thermotolerant in the study location, another deposited influences is the formation stratifications, this pressure the behaviour of the microbes on transport system, the deposition of microelement might be another influences increase that the population of the microbes and these are expressed in the figures moving in an exponential phase, the validation of the model show that both theoretical values and there expressed equations can be applied to monitor and predict the deposition and migration of thermotolerant in the study location.

4. Conclusion

The expressions from the figure has shows that the concentration of thermotolerant increase with depths, the developed theoretical values both predictive and validated compare faviourably well in an exponential phase, the condition of the concentration are influences by porosity of the formation, high degree of porosity were found to deposit in the study area, these pressure the migration of thermotolerant rapidly increase in its deposition, another influences on migration of the microbes are the depositions of microelement in the formation, since the deposition of microelements increase their population, the microelements as substrate, it means that the deposition of such micronutrient will increase the concentration of thermotolerant in the study area, the study is imperative because the validation of the theoretical values has show the authenticity of the derived expressions including the theoretical values that compared faviourably well.

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