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Research article

MODELING AND SIMULATION TO MONITOR STATIONARY PHASE OF THERMOTOLERANT TRANSPORT IN ORGANIC AND LATERITIC SOIL COLUMN OF PORT HARCOURT METROPOLIS

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Abstract

Mathematical modeling techniques were applied to monitor the behaviour of thermotolerant transport between organic and lateritic soil formation, the model were developed to monitor the rate of thermotolerant deposition between the formations, stationary phase of the microbes were the focus of the study, the structural setting of the formation were found to develop low void ratio due to high plasticity of lateritic soil, these conditions of the formations including other influences that cause the microbes to station between the stated formations of the soil, the developed model were simulated for validation, the theoretical values from the simulation were compared with theoretical vales, both parameters produce best fits thus generated increase in concentration, these condition can be attributed to low rate of void ration between the lateritic soil formation due it high degree of plasticity of the formation, the behaviour of the microbes are influenced by the structural condition of the strata as the microbes station between the lateritic soil developed constant increase of concentration between the strata. Experts in the field will applied this concept to monitor the behaviour of the thermotolerant transport process in risk assessment on environment pollution of soil in the study area.

Keywords: modeling and simulation, thermotolerant transport, organic and lateritic soil.

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1. Introduction

Modeling microbial processes in porous media is essential to improving our understanding of the biodegradation of contaminants and the movement of pathogens. Microbial processes incorporate physicochemical processes and biological processes. Microorganisms and their transport in the environment is a complex issue of growing concern. Most reactive transport models only consider physicochemical processes. The impact of biological processes in a flowing groundwater system can only be evaluated within this physicochemical framework (Murphy and Ginn, 2000 Eluozo, 2013). The physicochemical processes are primarily based on the physical structure and chemical properties of the subsurface flow system and porous media. Microbial mobility dominated by physicochemical interaction with the porous media is mainly described with the colloid infiltration model (Li, 2006). The transport behavior of microorganisms in the subsurface environment is of great significance with respect to the fate of pathogens associated with wastewater recharge, riverbank filtration, septic systems, feedlots, and land application of biosolids. A common element to most of these applications is that the associated aqueous solutions typically have relatively high concentrations of dissolved organic carbon. Thus, the potential influence of DOC on pathogen transport is of interest. The factors affecting the transport and fate of viruses and bacteria in the subsurface have received significant attention (e.g., Yates and Yates, 1988; Schijven and Hassanizadeh, 2000; Ginn et al., 2002,Eluozo,2013). Bacteriophages are often used as a surrogate to evaluate the transport and fate of pathogenic viruses. They serve as useful models because they are similar in size and structure to many enteric viruses in some condition, do not pose a human-health hazard, and are relatively inexpensive. MS-2 Bacteriophages was used in this study, and is considered a model virus for use in transport studies because it is relatively persistent during transport (e.g., Schijven, et al. 1999). MS-2 has been classified as a group I virus, which are those whose transport is considered to be influenced by soil characteristics such as pH, exchangeable iron, and organic matter content (Gerba and Keswick., 1981). Several prior studies have examined the transport of MS-2 in porous media (Hurst et al. 1980; Bales et al. 1993; 1997; Schijven, et al. 1999, 2002, 2003; Jin et al. 2000; Hijnen et al. 2005, Eluozo,2013). The objective of this study was to investigate the influence of dissolved organic carbon on MS-2 Bacteriophages transport in a sandy soil. Miscible-displacement experiments were conducted to examine the retention and transport of MS-2, at two influent concentrations, in the absence and presence of DOC. The experiments were conducted by Alexandra Chetochine. The results of the experiments were analyzed with a mathematical model that incorporated inactivation and rate-limited attachment/detachment.

2. Materials and method

Soil samples from several different boring locations, were collected at intervals of thirty centimeters each (30cm). Soil sample were collected in five different location, applying insitu method of sample collection, the soil sample were collect for analysis, standard laboratory analysis were collected to determine the uranium concentration through column experiment, the result were analysed to determine the influence on thermotolerant transport between organic and lateritic soil in the study area.

3. Developed 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]

$$K_d \frac{\partial^2 c_5}{\partial y^2} = K_n \frac{\partial c_5}{\partial x} \quad \ldots\ldots\ldots\ldots \tag{1}$$

Let $C_5 = YX$

$$\frac{\partial c_5}{\partial y} = Y^{11} X \quad \ldots\ldots\ldots\ldots \tag{2}$$

$$\frac{\partial c}{\partial x} = X^1 Y \quad \ldots\ldots\ldots\ldots \tag{3}$$

$$K_d Y^{11} X = -K_n X^1 Y \quad \ldots\ldots\ldots\ldots \tag{4}$$

$$K_d \frac{Y^{11}}{Y} = -K_n \frac{X^1}{X} \quad \ldots\ldots\ldots\ldots \tag{5}$$

$$K_d Y^{11} X = -K_n X^1 Y = -\beta^2 \quad \ldots\ldots\ldots\ldots \tag{6}$$

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

$$K_d Y^{11} = -\beta^2 \quad \ldots\ldots\ldots\ldots \tag{8}$$

$$Y^{11} + \frac{\beta^2}{K_d} = 0 \quad \ldots\ldots\ldots\ldots \tag{9}$$

Auxiliary equation

$$M^2 + \frac{\beta^2}{K_d} = 0 \quad \ldots\ldots\ldots\ldots \tag{10}$$

$$M = \pm i \frac{\beta}{\sqrt{K_d}} \quad \ldots\ldots\ldots\ldots \tag{11}$$

$$\therefore Y = A Cos \frac{\beta}{\sqrt{K_d}} y + B Sin \frac{\beta}{\sqrt{K_d}} y \quad \ldots\ldots\ldots\ldots \tag{12}$$

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

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

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

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

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

4 .Results and Discussion

Results and discussion from the expressed figures through the theoretical generated values are presented in tables and figures, the expression explain the rate of concentration through graphical representation for every condition assessed in the developed model equations

Table1: concentration of Thermotolerant at different depths

Depths [m]	Concentration [mg/l]
3	0.67
6	2.68
9	6.03
12	10.73
15	16.77
18	24.14
21	32.39
24	37.56
27	54.33
30	67.1

Table 2: concentration of Thermotolerant at different Time

Time	Concentration [mg/l]
10	0.67
20	2.68
30	6.03
40	10.73
50	16.77
60	24.14
70	32.39
80	37.56
90	54.33
100	67.1

Table: 3 Comparison of Theoretical and Experimental values at different depths

Depths [m]	Theoretical Values [mg/l]	Experimental values [Mg/l]
3	0.67	0.7
6	2.68	2.58
9	6.03	7.1
12	10.73	11.1
15	16.77	16.55
18	24.14	24.99
21	32.39	32.14
24	37.56	37.44
27	54.33	55.1
30	67.1	68.22

Table: 4 Comparison of Theoretical and Experimental values at different Time

Time	Theoretical Values [mg/l]	Experimental values [Mg/l]
10	0.67	0.7
20	2.68	2.58
30	6.03	7.1
40	10.73	11.1
50	16.77	16.55
60	24.14	24.99
70	32.39	32.14
80	37.56	37.44
90	54.33	55.1
100	67.1	68.22

Table 5: concentration of Thermotolerant at different Time

Depths [m]	Concentration [mg/l]
3	0.67
6	3.1
9	8.53
12	21.4
15	37.5
18	62.35
21	103.9
24	192
27	343.6
30	600

Table 6: concentration of Thermotolerant at different depths

Time	Concentration [mg/l]

10	**0.67**
20	**3.1**
30	**8.53**
40	**21.4**
50	**37.5**
60	**62.35**
70	**103.9**
80	**192**
90	**343.6**
100	**600**

Table: 7 Comparison of Theoretical and Experimental values at different depths

Depths [m]	Theoretical Values [mg/l]	Experimental values [Mg/l]
3	0.67	0.71
6	3.1	3.3
9	8.53	8.5
12	21.4	22.1
15	37.5	36.98
18	62.35	63.1
21	103.9	104.3
24	192	195
27	343.6	347.1
30	600	589

Table: 8 Comparison of Theoretical and Experimental values at different Time

Time	Theoretical Values [mg/l]	Experimental values [Mg/l]
10	0.67	0.71
20	3.1	3.3
30	8.53	8.5
40	21.4	22.1
50	37.5	36.98
60	62.35	63.1
70	103.9	104.3
80	192	195
90	343.6	347.1
100	600	589

Table 9: concentration of Thermotolerant at different Time

Time	Concentration [mg/l]
5	0.16
10	0.67

15	**1.5**
20	**2.68**
25	**4.19**
30	**6.04**
35	**8.21**
40	**10.7**
45	**13.5**
50	**33.54**

Table 10: concentration of Thermotolerant at different depths

Depths [m]	Concentration [mg/l]
3	0.16
6	0.67
9	1.5
12	2.68
15	4.19
18	6.04
21	8.21
24	10.7
27	13.5
30	33.54

Table: 11 Comparison of Theoretical and Experimental values at different Time

Time	Theoretical Values [mg/l]	Experimental values [Mg/l]
5	0.16	0.16
10	0.67	0.72
15	1.5	1.43
20	2.68	2.77
25	4.19	4.23
30	6.04	5.99
35	8.21	8.43
40	10.7	10.21
45	13.5	14.1
50	33.54	34.23

Table: 12 Comparison of Theoretical and Experimental values at Different Time

Depths	Theoretical Values [mg/l]	Experimental values [Mg/l]
1.5	0.16	0.16
3	0.67	0.72
4.5	1.5	1.43
6	2.68	2.77
7.5	4.19	4.23

9	**6.04**	**5.99**
10.5	**8.21**	**8.43**
12	**10.7**	**10.21**
13.5	**13.5**	**14.1**
15	**33.54**	**34.23**

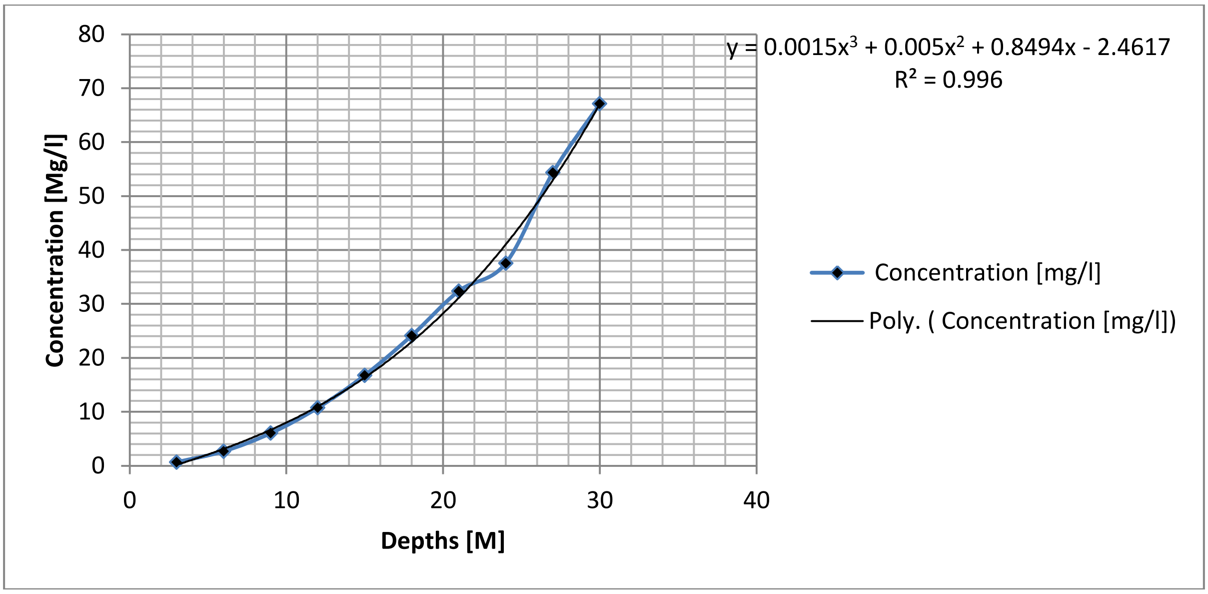

Figure 1: concentration of Thermotolerant at different depths

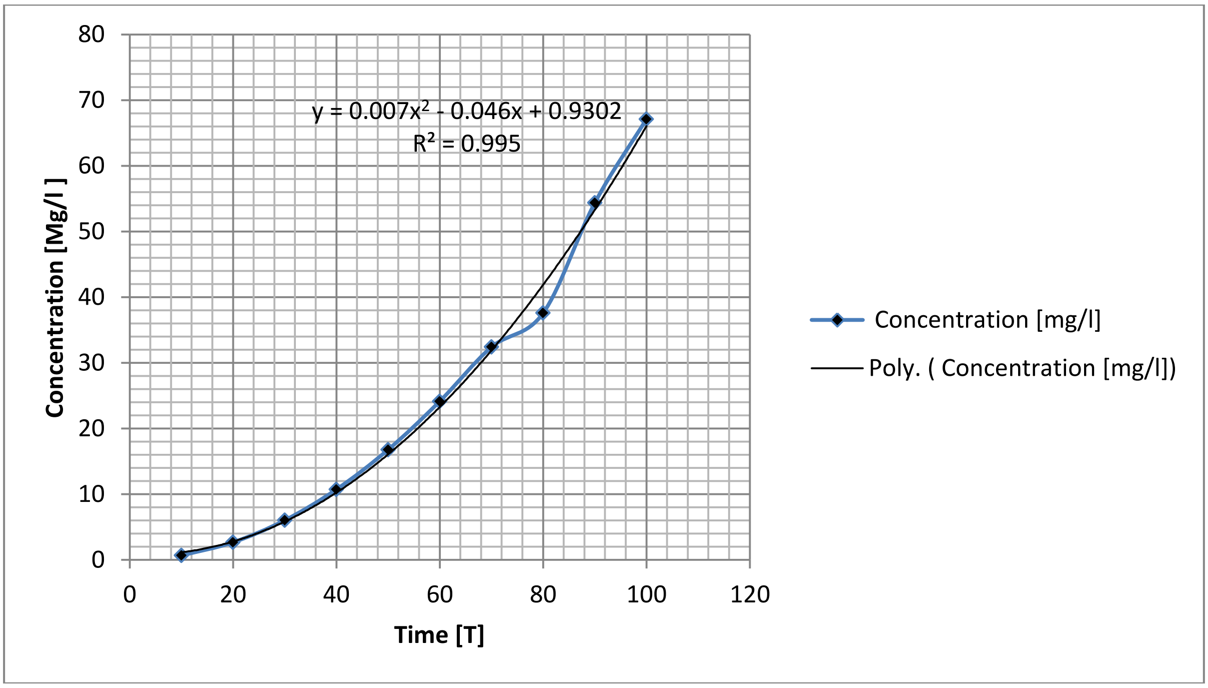

Figure: 2 concentration of Thermotolerant at Different Time

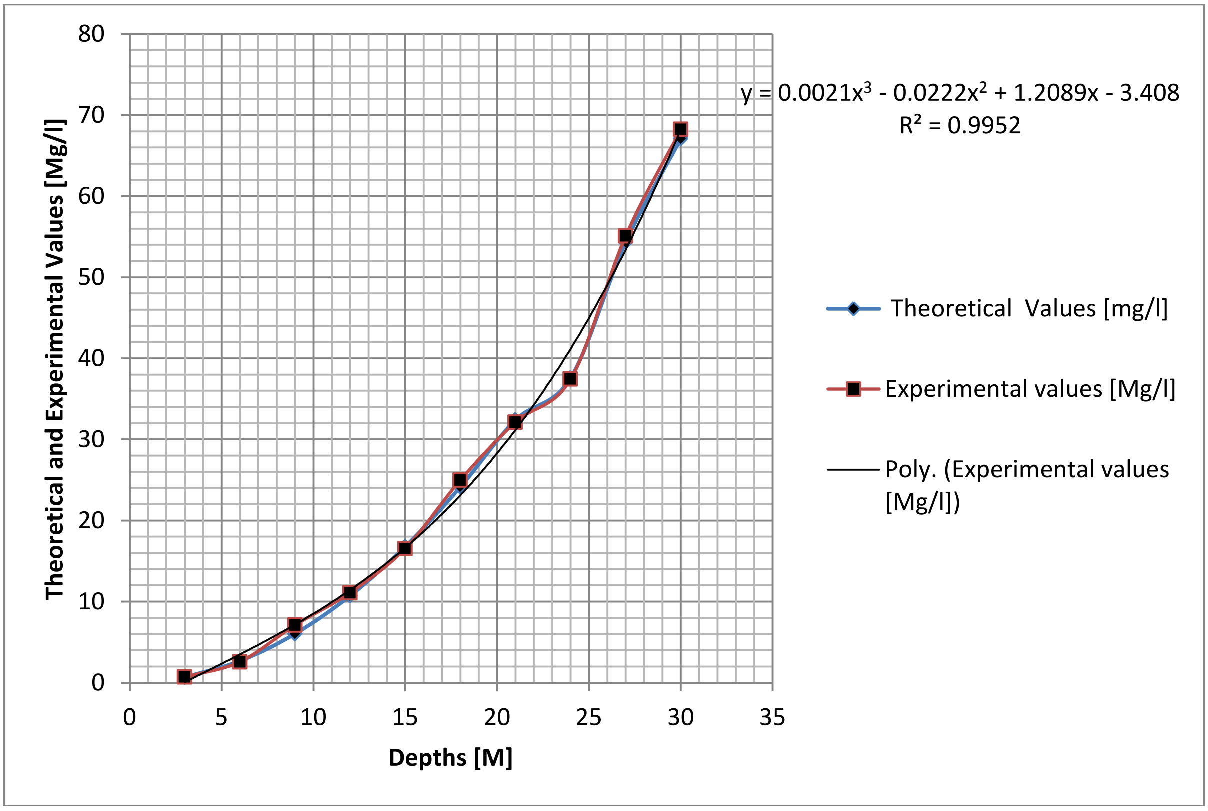

Figure: 3 Comparison of Theoretical and Experimental values at Different depths

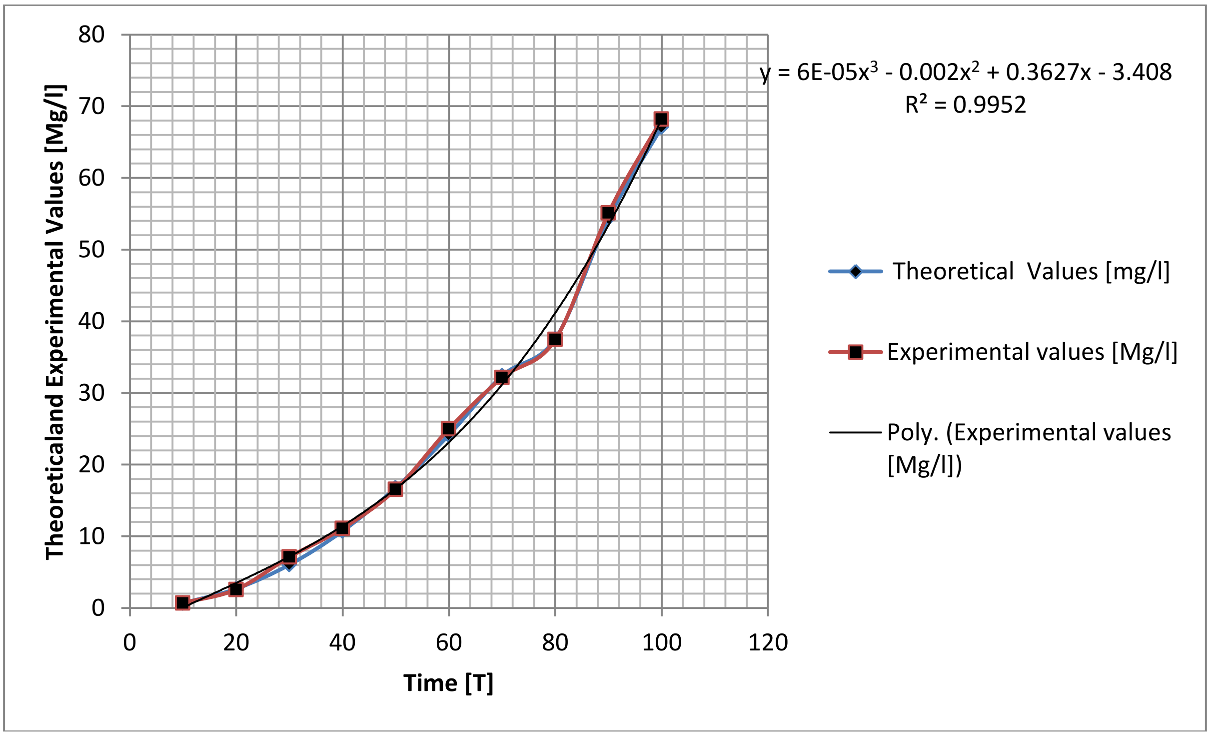

Figure: 4 Comparison of Theoretical and Experimental values at Different Time

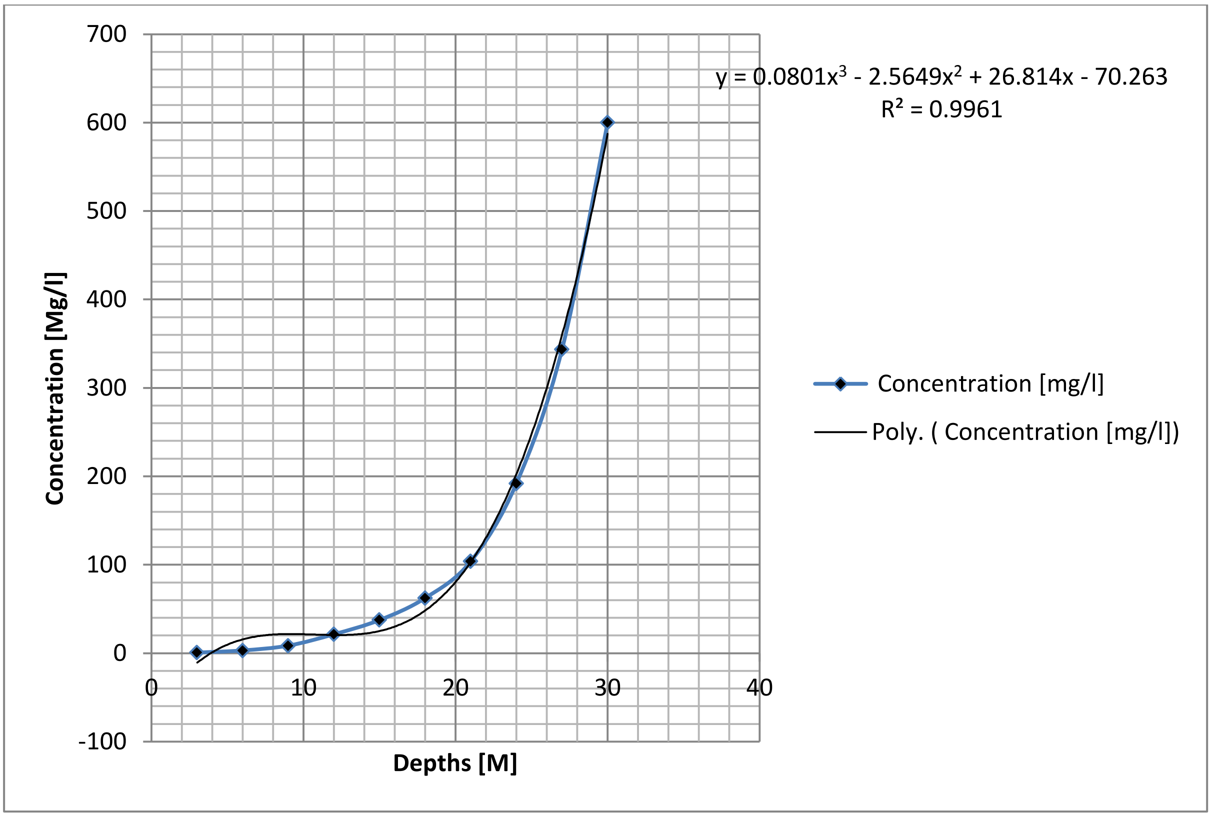

Figure: 5 concentration of Thermotolerant at different Depths

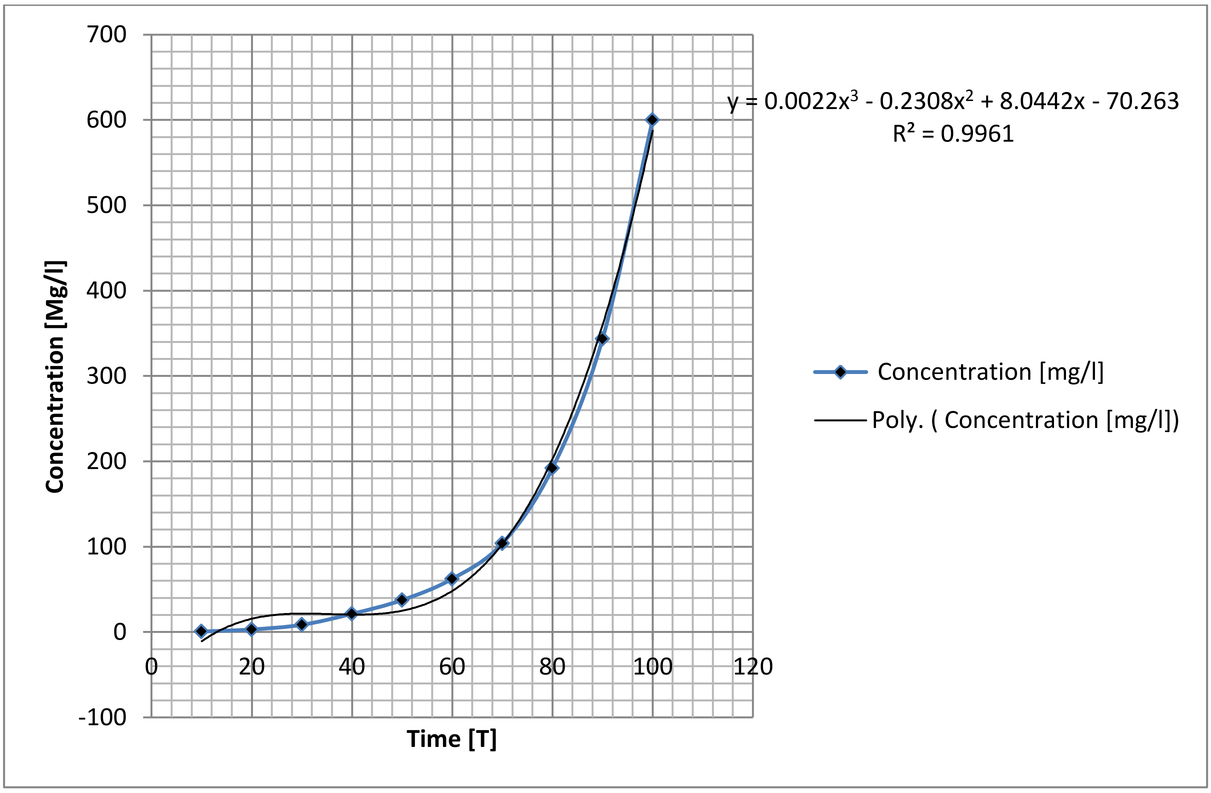

Figure: 6 concentration of Thermotolerant at Different Time

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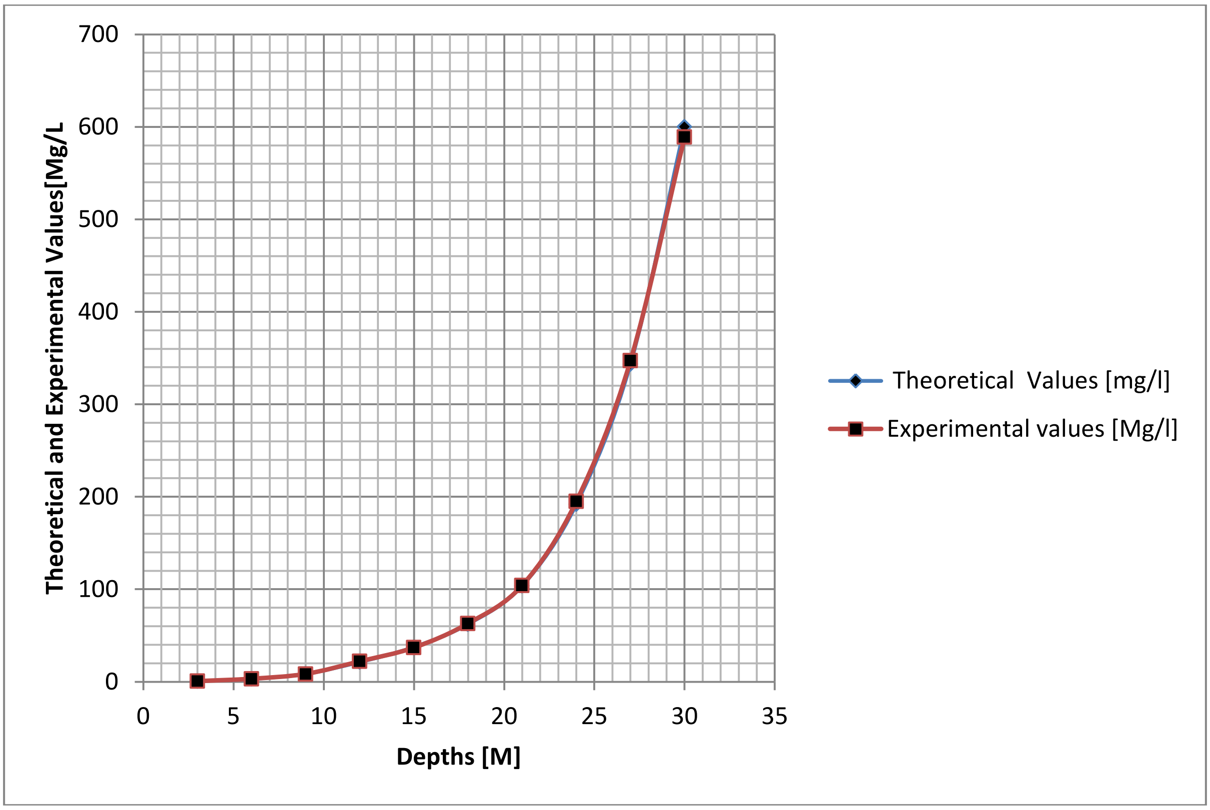

Figure : 7 Comparison of Theoretical and Experimental values at Different depths

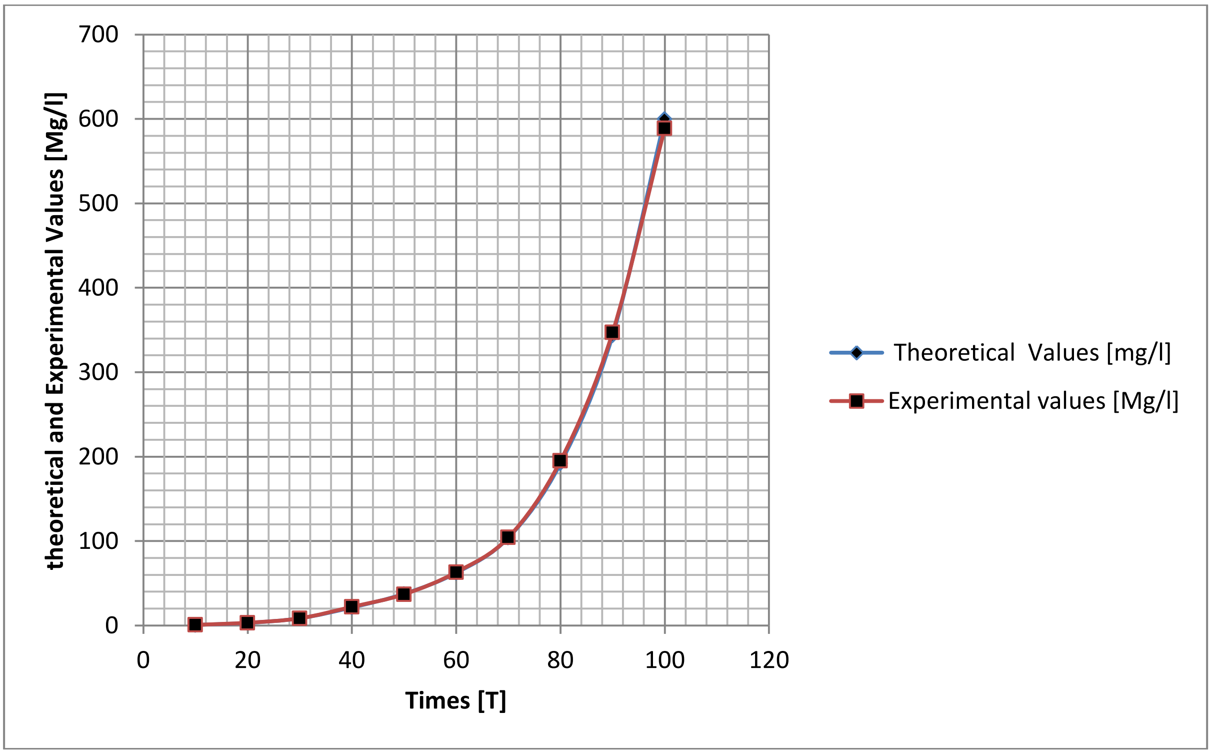

Figure: 8 Comparison of Theoretical and Experimental values at Different Time

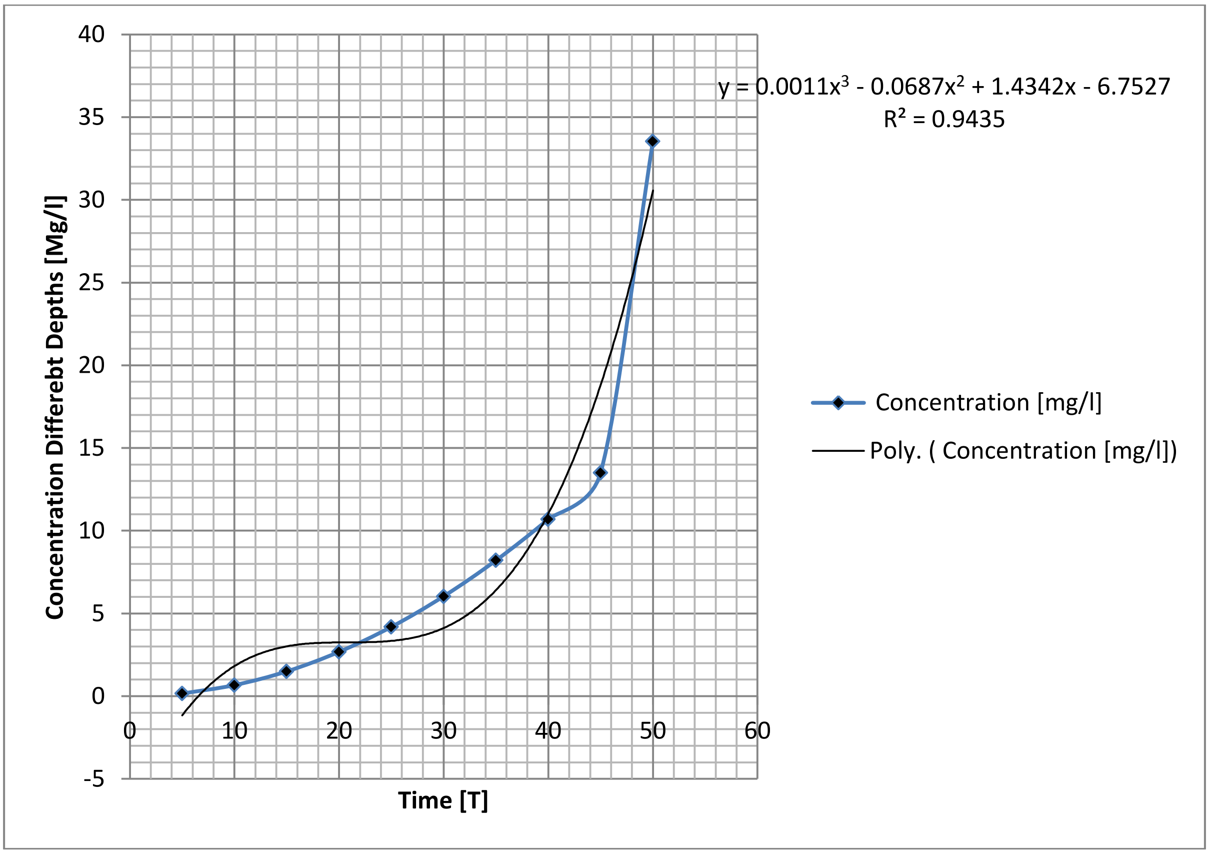

Figure: 9 concentration of Thermotolerant at Different Time

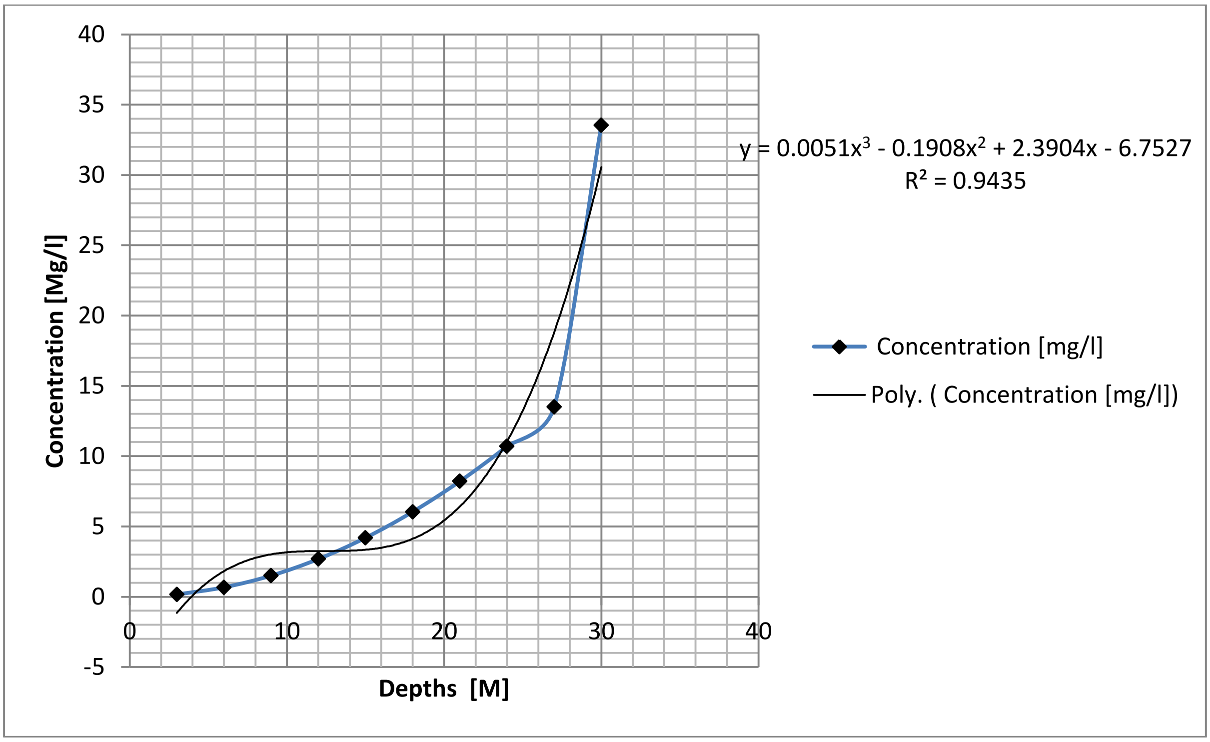

Figure: 10 concentration of Thermotolerant at Different Time

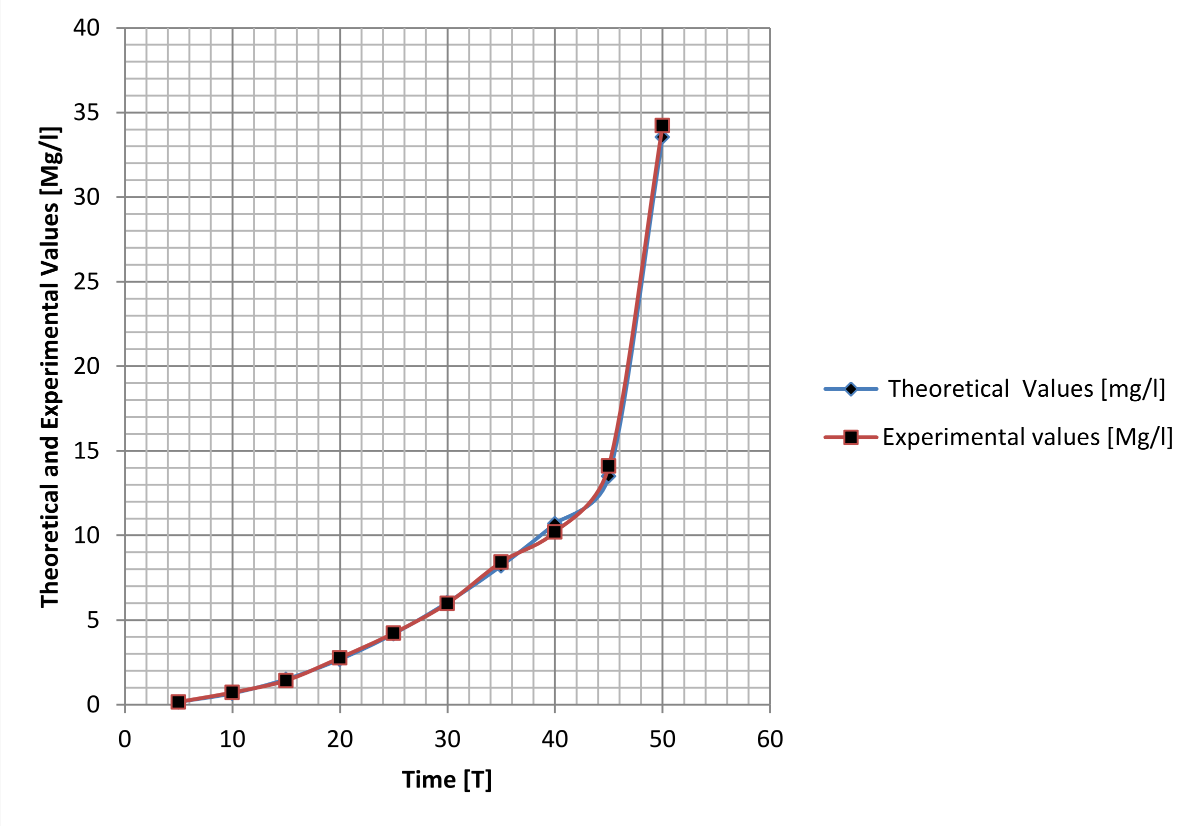

Figure: 11 Comparison of Theoretical and Experimental values at Different Time

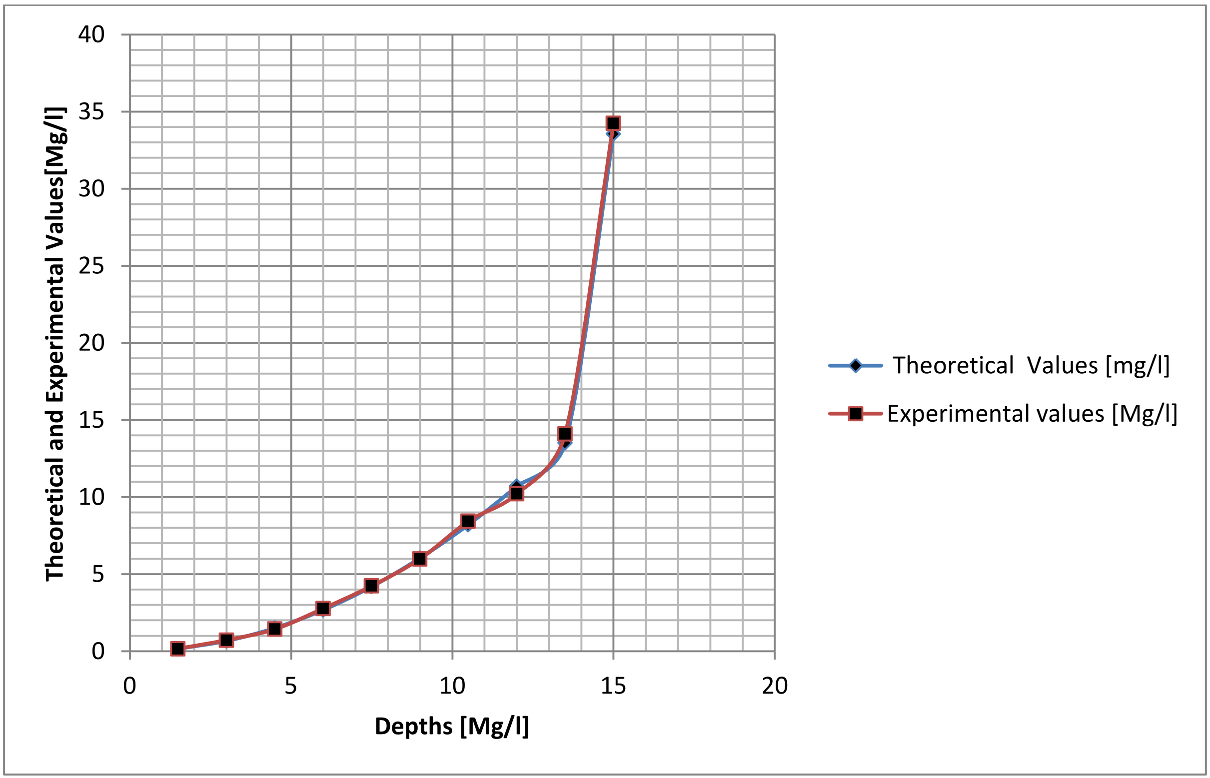

Figure: 12 Comparison of Theoretical and Experimental values at Different Depths

The deposition of thermotolerant in soil and water at two dimension flow direction has been expressed mathematically, the developed governing equation were expressed, considering the microbes deposited at stationary phase condition, the developed model from the derived solution generated a model that were simulated, the concept under normal condition were to expressed the behaviour of the microbes in the system, these conditions are under stationary phase of the microbial migration in the formations, base on these conditions, the generated theoretical values produced the following behaviour, figure 1 to 12 expressed the deposition at high increase of the concentration between the organic and lateritic soil formation, the behaviour of the thermotolerant expressed the influences of stationing between the organic and lateritic soil formation, it was discovered that since there is plasticity content in lateritic soil formation. despite high degree of saturation, the influences from low void ratio in the formation developed low migration generation high concentration between the lateritic soil, such influences developed stationary phase as it is expressed in the figures showing increase in concentration between the organic and lateritic soil formation. Generated theoretical values were compared with the experimental value, it produced best fit, this expression shows the validation of the developed model under stationary phase condition of thermotolerant deposition in organic and lateritic soil formation, the concentration varies as simulation of the model applied different constant ant variation of concentration expressed from the figures, the concentration at various rate of concentration were simulated, variation of velocity were applied on the simulation process, but the results developed increase in concentration from organic to lateritic soil formation , these are under the influences of observed low void ratio and high plasticity of lateritic despite high rain intensities in the study location.

5. Conclusion

The developed mathematical model for the deposition of thermotolerant in organic and lateritic soil formation generated theoretical values from the simulated model, the generated theoretical values were compared with experimental values, both parameters compared faviourably well establishing a best fit in all the figures from the studies, more so the model were simulated by varying some parameters that may deposit different parameters, such as velocity of transport including permeability and concentration in the study area. The variation of these parameters influences the transport system of the microbes as it is expressed in the study area. This model will definitely improve the predictive techniques of monitoring the deposition of thermotolerant deposition in stationary phase condition; the behaviour of the microbes in terms of pollution in organic and lateritic soil formation can be predicted for monitoring and evaluation in risk assessment in the study location.

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