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Research article

SIMULATING ENTEROMOBACTER TRANSPORT INFLUENCED BY VOID RATIO IN HOMOGENEOUS COARSE FORMATIONS IN EMUOHA, RIVERS STATE OF NIGERIA

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Abstract

Enteromobacter deposition has been found predominant in the deltaic environment, such predominant condition were monitored in some investigations carried out that express various concentration in the study area, but better solution to engineer this contaminant were not made available from the investigation, the migration were found to be influenced by the deltaic nature of the formations, this were reflected on the rate of concentration at different deposition, the present of this contaminant has cause lots to human ill health in settlements, to develop better solution, the expression of mathematical model were found suitable for the study, this were imperative so that better solution will be applied to engineer the contaminants out from the study location, the deposition of the microbes generate a system formulated whereby mathematical governing equation were developed, the expression were derived to generate model simulated that determine the deposition rate and behaviour of the microbes at every formations. The study is imperative because experts will definitely improve their methods of engineering out this contaminant through this application in the study area. **Copyright © AJEEPR, all rights reserved.**

Keywords: Enteromobacter transport void ratio, and homogeneous coarse formation

1 Introduction

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). 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. Governing Equation

$$V\frac{\partial Cs_3}{\partial t} = Mb\frac{\mu_o}{\gamma_o}\frac{\partial Cs_3}{\partial z} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

We approach the system by using Bernoulli's method of separation of variables.

$$Cs_3 = ZT \quad (2)$$

$$\frac{\partial Cs_3}{\partial t} = ZT^1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$\frac{\partial Cs_3}{\partial z} = Z^1T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Hence, we put (3) and (4) into (2), so that we have

$$V\frac{ZT^1}{T} = M_b\frac{\mu_o}{\gamma_o}\frac{Z^1T}{T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

i.e. $$\frac{VT^1}{T} = M_b\frac{\mu_o}{\gamma_o}\frac{Z^1}{Z} - \lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Hence $V\dfrac{T^1}{T} + \lambda^2 = 0$ ………………… (7)

i.e. $Z^1 + \dfrac{\lambda^2}{V}Z = 0$ ………………… (8)

And $M_b\dfrac{\mu_o}{\gamma_o}T^1 + \lambda^2 T = 0$ ………………… (9)

From (27) $X = ACos\dfrac{\lambda}{V}Z + BSin\dfrac{\lambda}{V}Z$ ………………… (10)

And (21) gives

$$T = Cs_o\ell^{\frac{-\lambda^2}{M_b\frac{\mu_o}{\gamma_o}}t} \qquad \text{…………………} \quad (11)$$

By substituting (10) and (11) into (2), we get

$$Cs_3 = \left[ACos\frac{\lambda}{V}t + B\,Sin\frac{\lambda}{\sqrt{V}}Z\right]Cos\ell^{\frac{-\lambda^2}{M_b\frac{\mu_o}{\gamma_o}}t} \qquad \text{…………………} \quad (12)$$

If x = D/ V and x = V.T

$$Cs_3 = \left[ACos\frac{\lambda}{V}\frac{d}{v} + B\,Sin\frac{\lambda}{\sqrt{V}}V.t\right]Cos\ell^{\frac{-\lambda^2}{M_b\frac{\mu_o}{\gamma_o}}t} \qquad \text{……………………………} \quad (13)$$

Subject to this condition we have

$$Cs_o = Ac \qquad \text{……………} \quad (14)$$

comparable circumstances are expressed in equation (13) ammonia depositions migrating to organic soil are establish to deposit elevated concentration of microelement, due the low degree of void ratio, therefore the propensity of buildup waiting for high degree of saturation is to enable it migrate to were degree of void ratio deposit higher other formation, similar condition developed the composition of these parameter integration in equation (13) were the concentration of the substrate at the state experiences variations, condition, so the formation stratum determined the expressed variable that developed model denoted as C_s = Ac in equation (13).

Equation (14) becomes

$$Cs_3 = Cs_o \ell \frac{-\lambda^2}{M_b \frac{\mu_o}{\gamma_o}} t \; Cos \frac{\lambda}{V} Z \qquad \ldots\ldots\ldots\ldots\ldots \; (15)$$

Again at $\frac{\partial Cs_3}{\partial t}\Big| \; t = 0, \; B$

Equation (35) becomes

$$\frac{\partial Cs_2}{\partial t} = \frac{\lambda}{\sqrt{V}} Cos \ell^{\frac{-\lambda^2}{M_b \frac{\mu_o}{\gamma_o}} t} \; Sin \frac{\lambda}{V} x \qquad \ldots\ldots\ldots\ldots \; (16)$$

i.e. $0 = -Cs_o \frac{\lambda}{\sqrt{V}} \; Sin \frac{\lambda}{V} 0$

$Cs_o \frac{\lambda}{\sqrt{V}} \neq 0$ Considering NKP

Considered in the state of microbial transport determined the rate of reaction that may be due to inhibition from other influence that deposit in soil and water environment.

$$0 = -Cs_o \frac{\lambda}{V} \; Sin \frac{\lambda}{V} B \qquad \ldots\ldots\ldots\ldots\ldots \; (17)$$

$$\Rightarrow \frac{\lambda}{\sqrt{V}} = \frac{n\pi\sqrt{V}}{2} \qquad \ldots\ldots\ldots\ldots\ldots \; (18)$$

$$\Rightarrow \lambda = \frac{n\pi\sqrt{V}}{2} \qquad \ldots\ldots\ldots\ldots\ldots \; (19)$$

So that equation (61)

$$Cs_3 = Cs_o \ell^{\frac{-n^2\pi^2 V}{2M_b \frac{\mu_o}{\gamma_o}}} \; Cos \frac{n\pi\sqrt{V}}{2\sqrt{V}} Z \qquad \ldots\ldots\ldots\ldots\ldots \; (20)$$

$$\Rightarrow Cs_3 = Cs_o \ell^{\frac{-n^2\pi^2 V}{2M_b \frac{\mu_o}{\gamma_o}}} t \; Cos \frac{n\pi}{2} Z \qquad \ldots\ldots\ldots\ldots\ldots\ldots \; (21)$$

$$\Rightarrow \; Cs_3 = Cs_o \, \ell^{\frac{-n^2\pi^2 V}{2M_b \frac{\mu_o}{\gamma_o}}} \frac{d}{v} \, Cos \frac{n\pi}{2} v.t \tag{22}$$

2. Materials and method

Soil samples from several different borehole locations, were collected at intervals of three metres each (3m). 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 soil formation, the result were analysed to determine the rate of enteromobacter concentration between coarse formation through column experiment in the study area.

3. Results and Discussion

Theoretical and experimental values from every condition on the developed model are expressed in figures and tables below.

Table: 1 concentration of the Enteromobacter at Different Depth

Depths [M]	Concentration [Mg/l]
3	8.68E-11
6	1.02E-11
9	2.31E-11
12	4.13E-11
15	6.25E-11
18	9.25E-11
21	1.26E-10
24	1.64E-10
27	2.08E-10
30	2.56E-10

Table: 2 concentration of the Enteromobacter at Different Time

Time [Days]	Concentration [Mg/l]
10	8.68E-11
20	1.02E-11
30	2.31E-11
40	4.13E-11
50	6.25E-11
60	9.25E-11
70	1.26E-10
80	1.64E-10

90	**2.08E-10**
100	**2.56E-10**

Table: 3 Comparison of theoretical and experimental values of Enteromobacter at Different Depths

Depths [M]	Theoretical values [Mg/l]	Experimental Values [Mg/L]
3	8.68E-11	8.81E-11
6	1.02E-11	1.44E-11
9	2.31E-11	2.53E-11
12	4.13E-11	4.44E-11
15	6.25E-11	6.15E-11
18	9.25E-11	9.66E-11
21	1.26E-10	1.66E-10
24	1.64E-10	1.61E-10
27	2.08E-10	2.12E-10
30	2.56E-10	2.66E-10

Table: 4 Comparison of theoretical and experimental values of Enteromobacter at Different Time

Time [Days]	Theoretical values [Mg/l]	Experimental Values [Mg/L]
10	8.68E-11	8.81E-11
20	1.02E-11	1.44E-11
30	2.31E-11	2.53E-11
40	4.13E-11	4.44E-11
50	6.25E-11	6.15E-11
60	9.25E-11	9.66E-11
70	1.26E-10	1.66E-10
80	1.64E-10	1.61E-10
90	2.08E-10	2.12E-10
100	2.56E-10	2.66E-10

Table: 5 concentration of the Enteromobacter at Different Depth

Depths [M]	Concentration [Mg/l]
3	4.99E-03
6	9.99E-03
9	0.014
12	0.019
15	0.024
18	0.029
21	0.034

24	**0.039**
27	**0.044**
30	**0.049**

Table: 6 concentration of the Enteromobacter at Different Time

Time [Days]	**Concentration [Mg/l]**
10	**4.99E-03**
20	**9.99E-03**
30	**0.014**
40	**0.019**
50	**0.024**
60	**0.029**
70	**0.034**
80	**0.039**
90	**0.044**
100	**0.049**

Table: 7 Comparison of theoretical and experimental values of Enteromobacter at Different Time

Depths [M]	**Theoretical values [Mg/l]**	**Experimental Values [Mg/L]**
3	**4.99E-03**	**5.11E-03**
6	**9.99E-03**	**9.87E-03**
9	**0.014**	**1.50E-02**
12	**0.019**	**2.10E-02**
15	**0.024**	**2.70E-02**
18	**0.029**	**3.10E-02**
21	**0.034**	**3.60E-02**
24	**0.039**	**4.10E-02**
27	**0.044**	**4.70E-02**
30	**0.049**	**5.10E-02**

Table: 8 Comparison of theoretical and experimental values of Enteromobacter at Different Time

Time [Days]	**Theoretical values [Mg/l]**	**Experimental Values [Mg/L]**
10	**4.99E-03**	**5.11E-03**
20	**9.99E-03**	**9.87E-03**
30	**0.014**	**1.50E-02**
40	**0.019**	**2.10E-02**
50	**0.024**	**2.70E-02**
60	**0.029**	**3.10E-02**

70	**0.034**	**3.60E-02**
80	**0.039**	**4.10E-02**
90	**0.044**	**4.70E-02**
100	**0.049**	**5.10E-02**

Table: 9 concentration of the Enteromobacter at Different Time

Depths [M]	Concentration [Mg/l]
3	2.57E-11
6	1.02E-15
9	2.31E-15
12	4.11E-15
15	6.42E-15
18	9.24E-15
21	1.26E-14
24	1.64E-14
27	2.02E-14
30	2.57E-14

Table: 10 Comparison of theoretical and experimental values of Enteromobacter at Different Depths

Depths [M]	Theoretical values [Mg/l]	Experimental Values [Mg/L]
3	2.57E-11	2.61E-11
6	1.02E-15	1.11E-15
9	2.31E-15	2.44E-15
12	4.11E-15	4.47E-15
15	6.42E-15	6.77E-15
18	9.24E-15	9.11E-15
21	1.26E-14	1.29E-14
24	1.64E-14	1.89E-14
27	2.02E-14	2.18E-14
30	2.57E-14	2.63E-14

Table: 11 Comparison of theoretical and experimental values of Enteromobacter at Different Time

Time [Days]	Theoretical values [Mg/l]	Experimental Values [Mg/L]
10	2.57E-11	2.61E-11
20	1.02E-15	1.11E-15
30	2.31E-15	2.44E-15
40	4.11E-15	4.47E-15
50	6.42E-15	6.77E-15

60	**9.24E-15**	**9.11E-15**
70	**1.26E-14**	**1.29E-14**
80	**1.64E-14**	**1.89E-14**
90	**2.02E-14**	**2.18E-14**
100	**2.57E-14**	**2.63E-14**

Table: 12 concentration of the Enteromobacter at Different Time

Depths [M]	Concentration [Mg/l]
3	3.56E-06
6	7.13E-06
9	1.07E-05
12	1.42E-05
15	1.78E-05
18	2.14E-05
21	2.49E-05
24	2.85E-05
27	3.21E-05
30	3.56E-05

Table: 13 concentration of the Enteromobacter at Different Time

Time [Days]	Concentration [Mg/l]
10	3.56E-06
20	7.13E-06
30	1.07E-05
40	1.42E-05
50	1.78E-05
60	2.14E-05
70	2.49E-05
80	2.85E-05
90	3.21E-05
100	3.56E-05

Table: 14 Comparison of theoretical and experimental values of Enteromobacter at Different Time

Depths [M]	Theoretical values [Mg/l]	Experimental Values [Mg/L]
3	3.56E-06	3.66E-06
6	7.13E-06	7.67E-06
9	1.07E-05	1.03E-05
12	1.42E-05	1.37E-05

15	**1.78E-05**	**1.88E-05**
18	**2.14E-05**	**2.22E-05**
21	**2.49E-05**	**2.54E-05**
24	**2.85E-05**	**2.87E-05**
27	**3.21E-05**	**3.34E-05**
30	**3.56E-05**	**3.61E-05**

Table: 15 Comparison of theoretical and experimental values of Enteromobacter at Different Time

Time [Days]	Theoretical values [Mg/l]	Experimental Values [Mg/L]
10	**3.56E-06**	**3.66E-06**
20	**7.13E-06**	**7.67E-06**
30	**1.07E-05**	**1.03E-05**
40	**1.42E-05**	**1.37E-05**
50	**1.78E-05**	**1.88E-05**
60	**2.14E-05**	**2.22E-05**
70	**2.49E-05**	**2.54E-05**
80	**2.85E-05**	**2.87E-05**
90	**3.21E-05**	**3.34E-05**
100	**3.56E-05**	**3.61E-05**

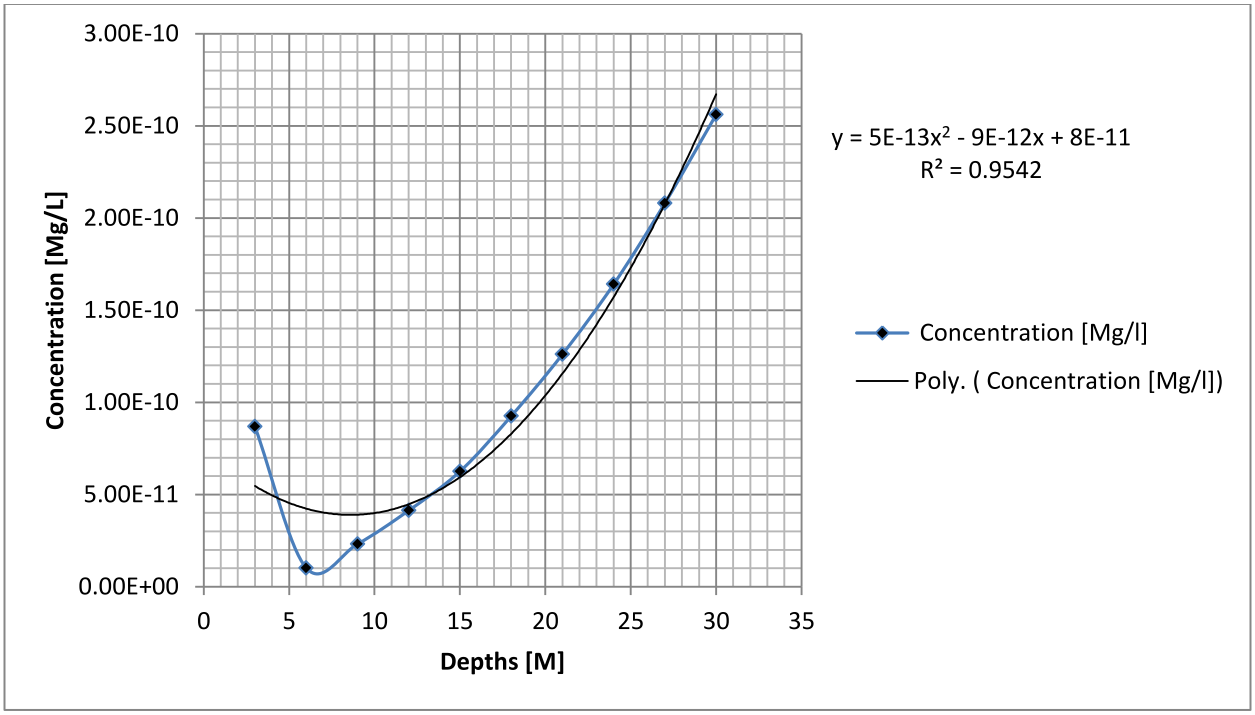

Figure: 1 concentration of the Enteromobacter at Different Depths

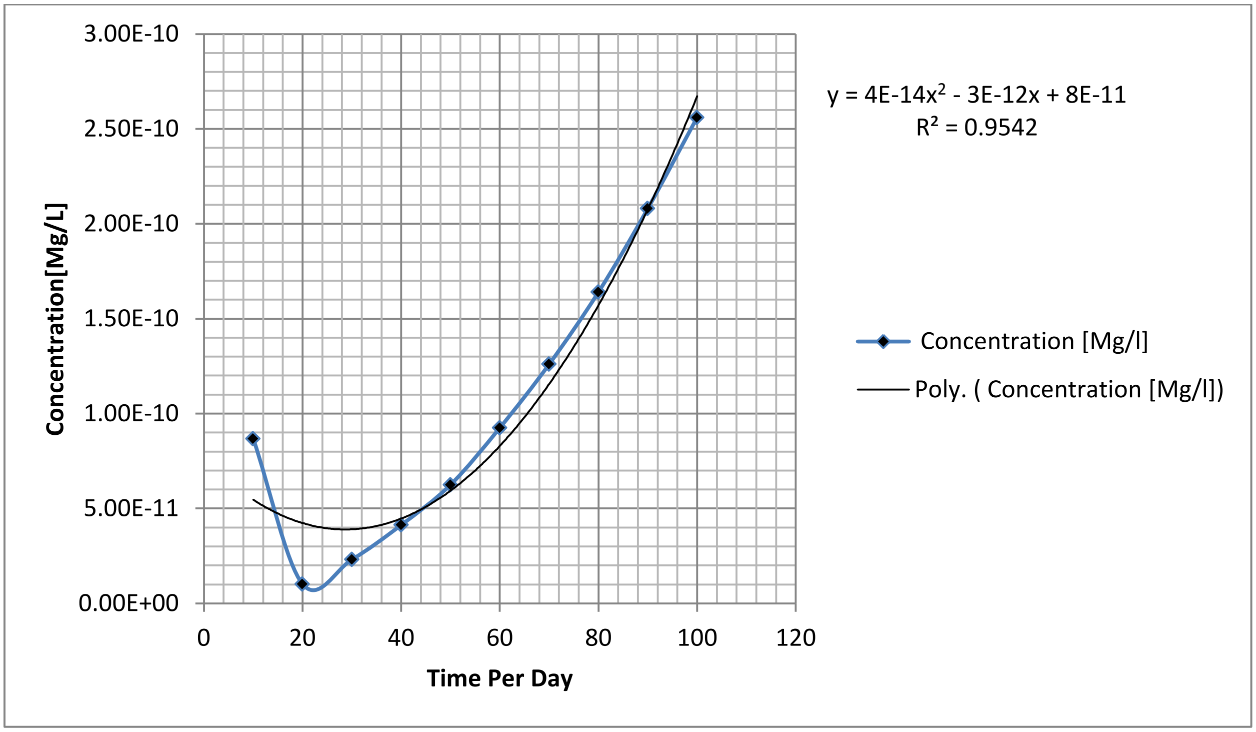

Figure: 2 concentration of the Enteromobacter at Different Time

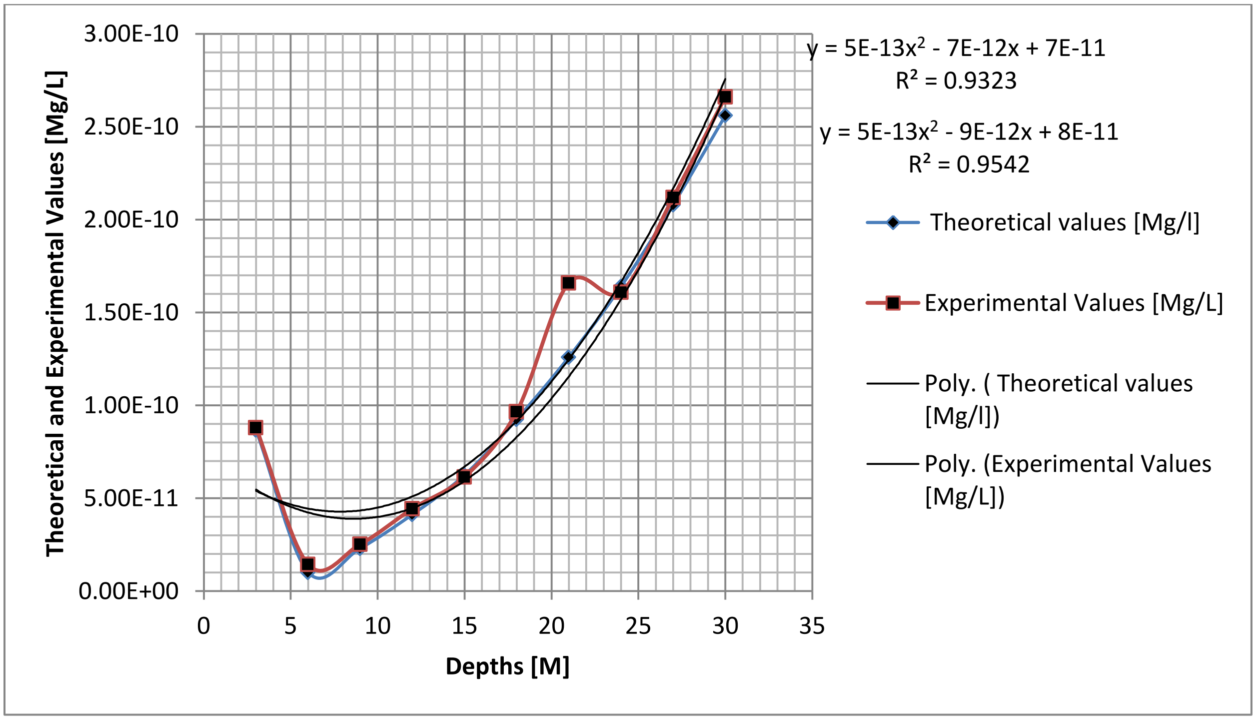

Figure 3 Comparison of Theoretical and experimental values of Enteromobacter at Different Depths

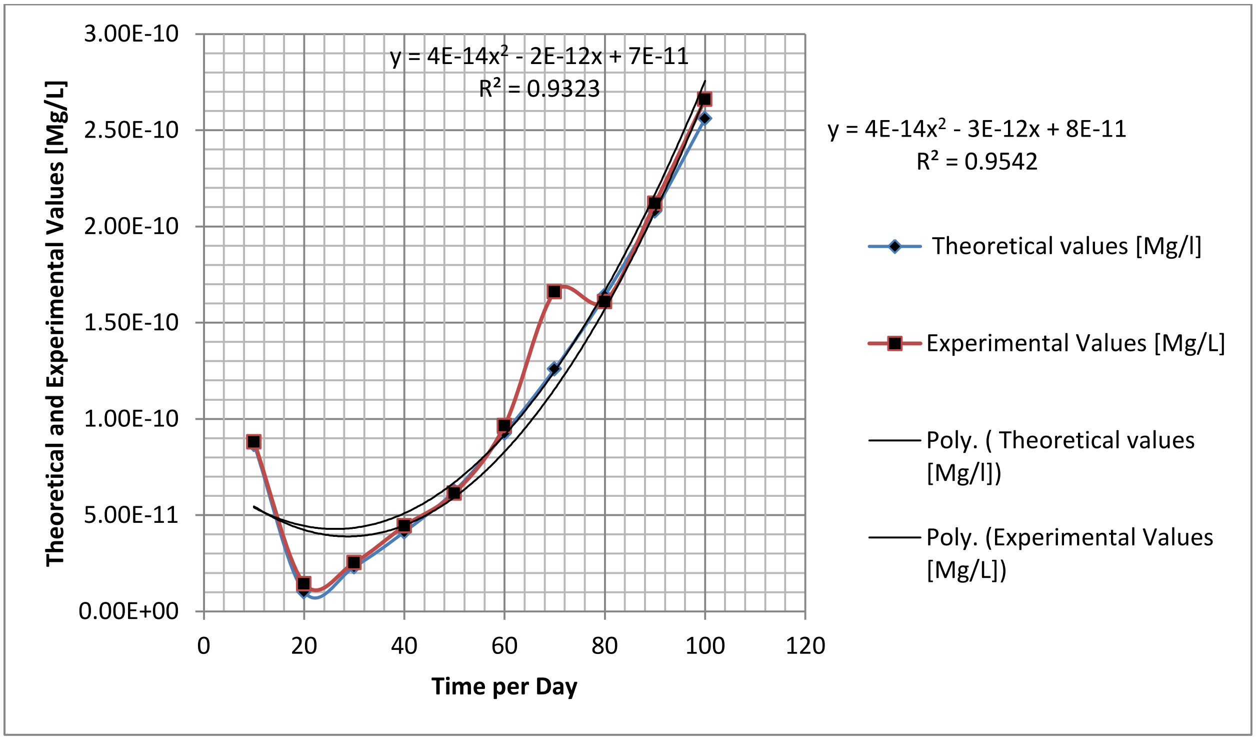

Figure: 4 Comparison of Theoretical and experimental values of Enteromobacter at Different Time

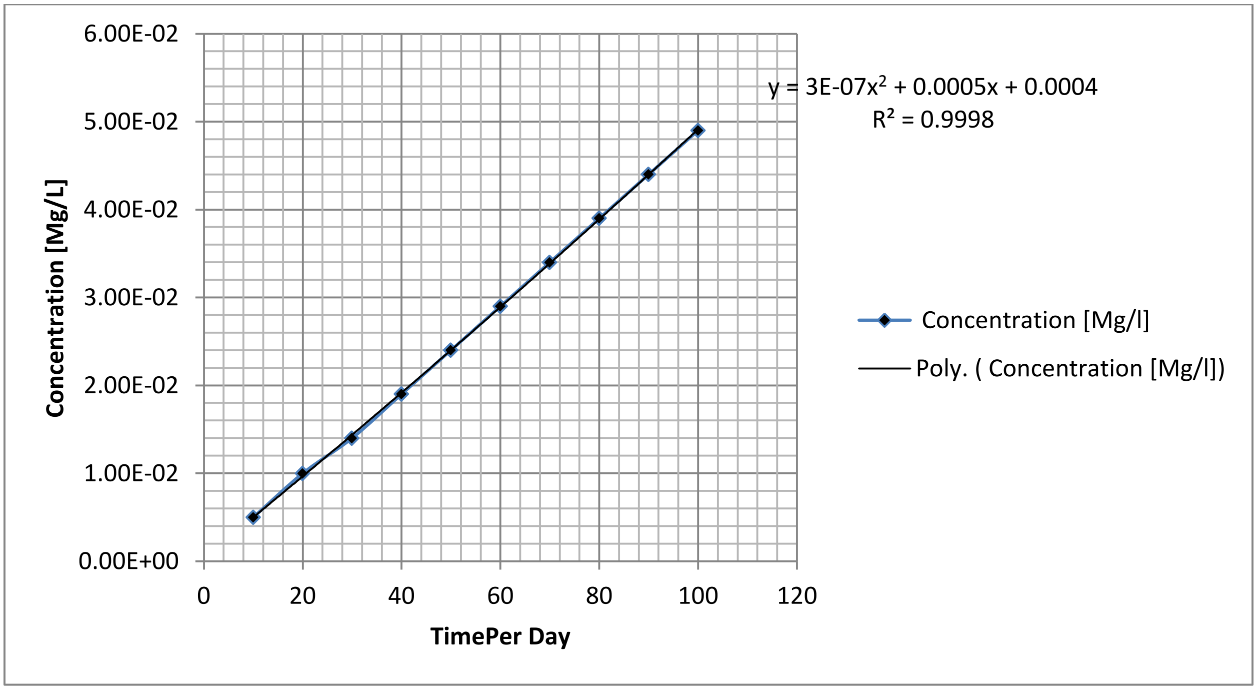

Figure: 5 concentration of the Enteromobacter at Different Time

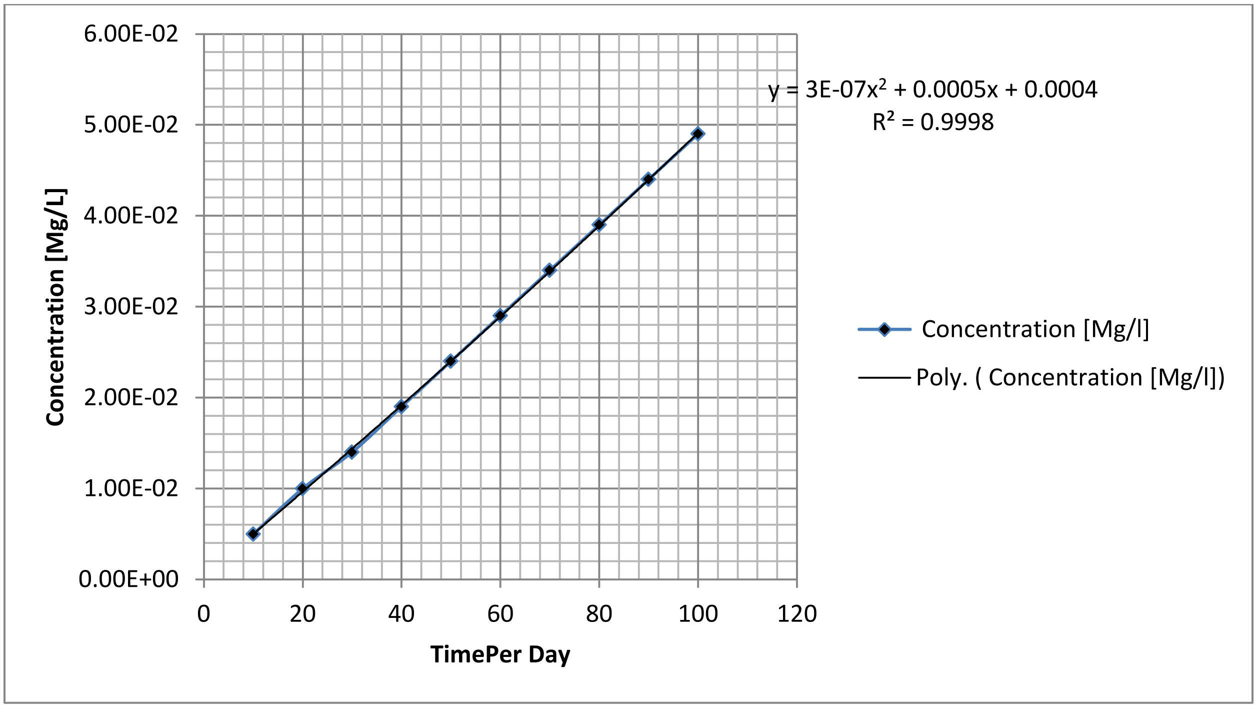

Figure: 6 concentration of the Enteromobacter at Different Time

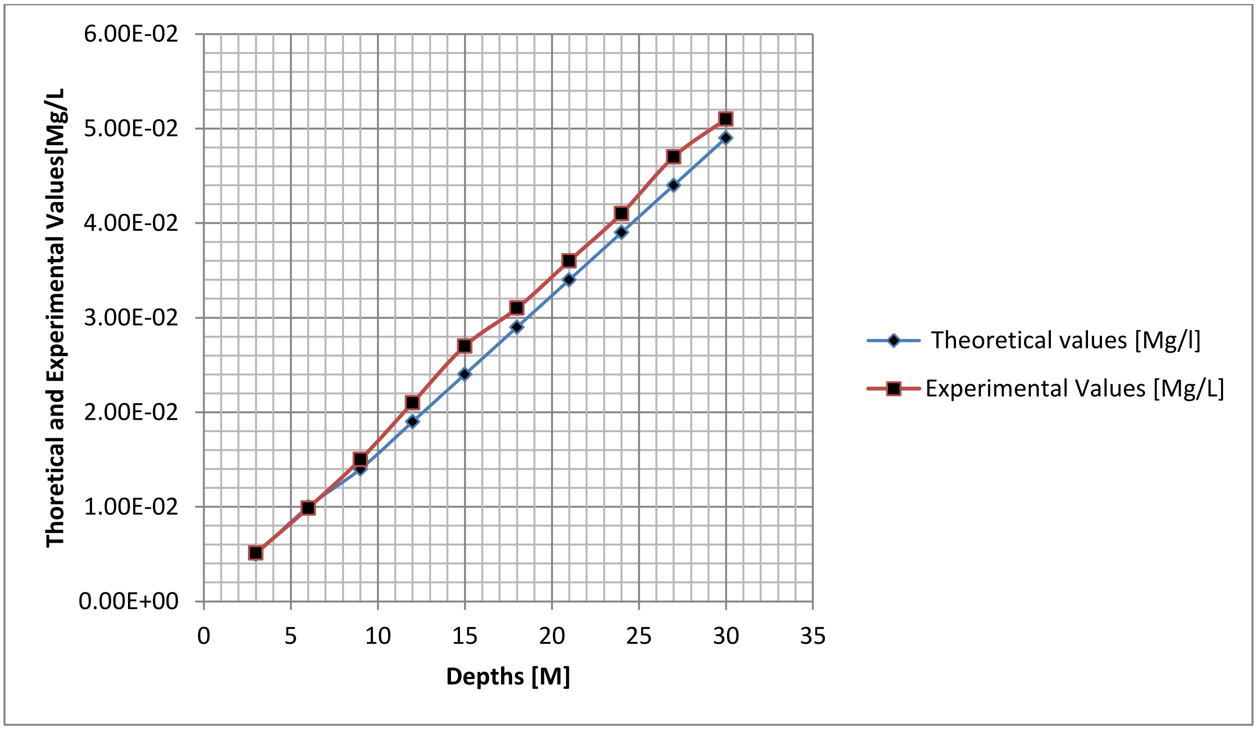

Figure: 7 Comparison of Theoretical and experimental values of Enteromobacter at Different Depths

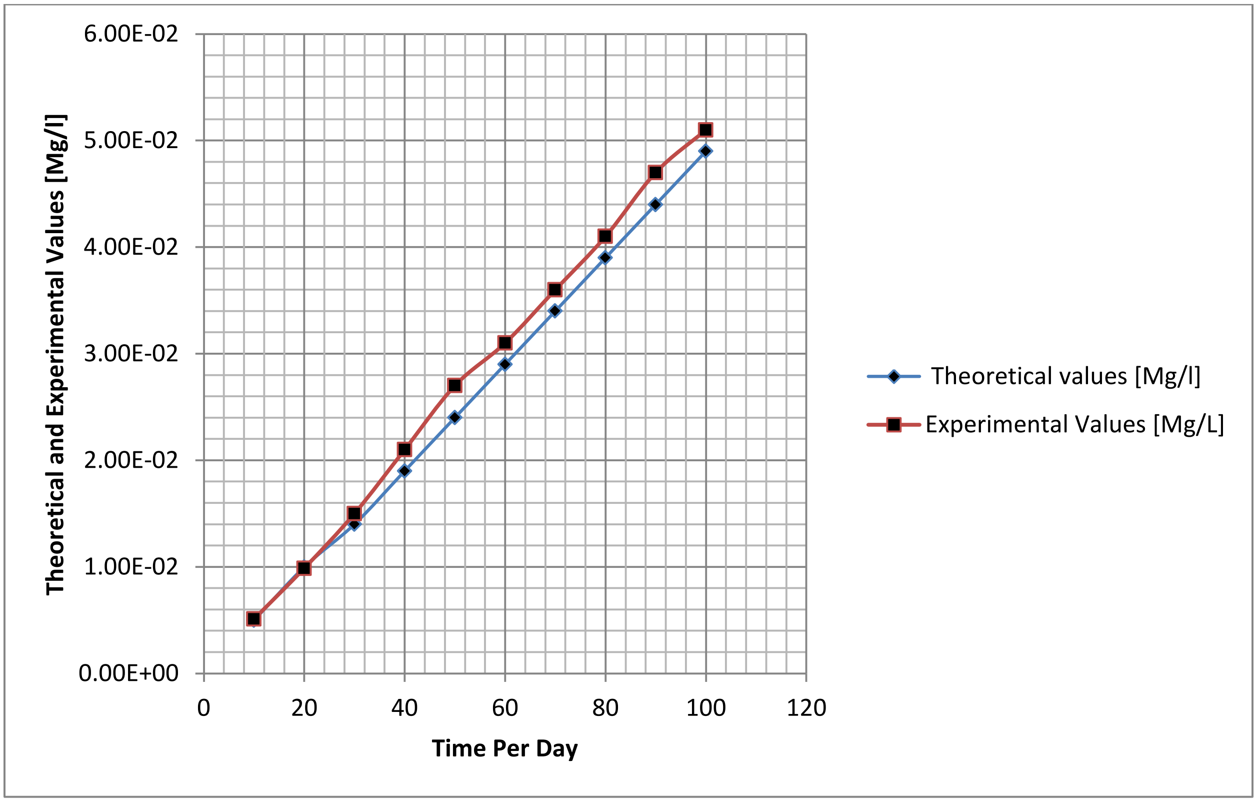

Figure: 8 Comparison of Theoretical and experimental values of Enteromobacter at Different Time

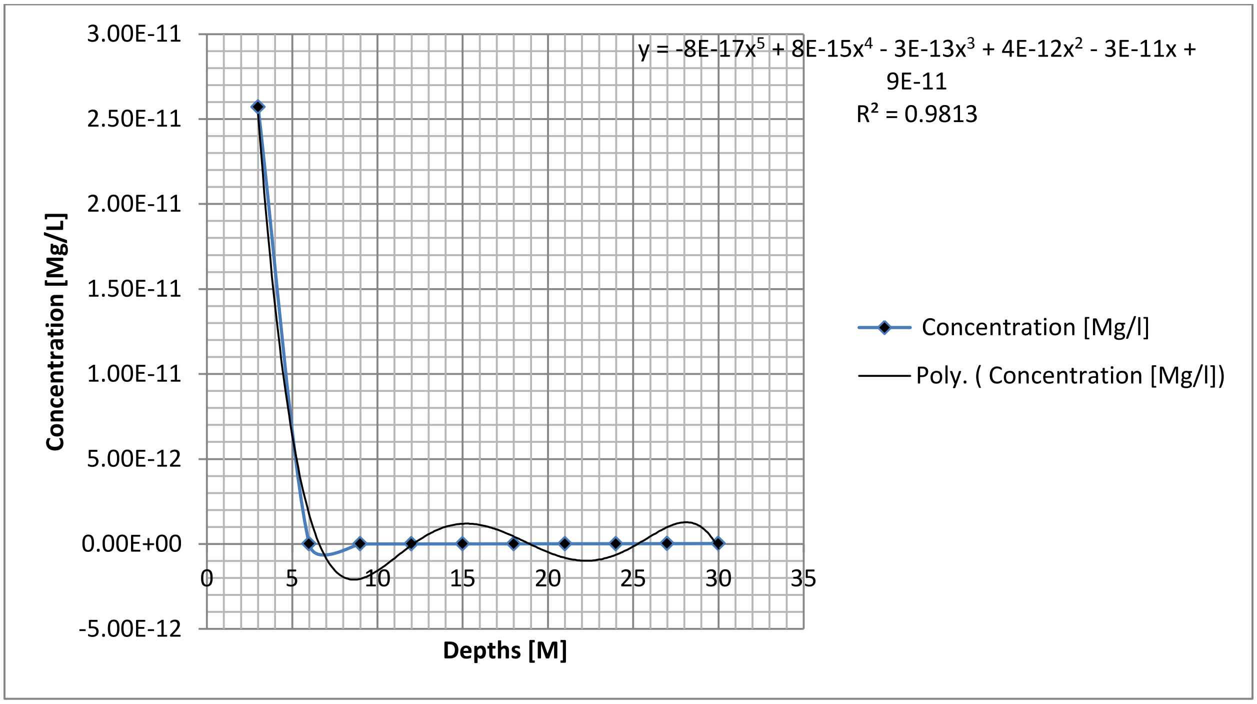

Figure: 9 concentration of the Enteromobacter at Different Depths

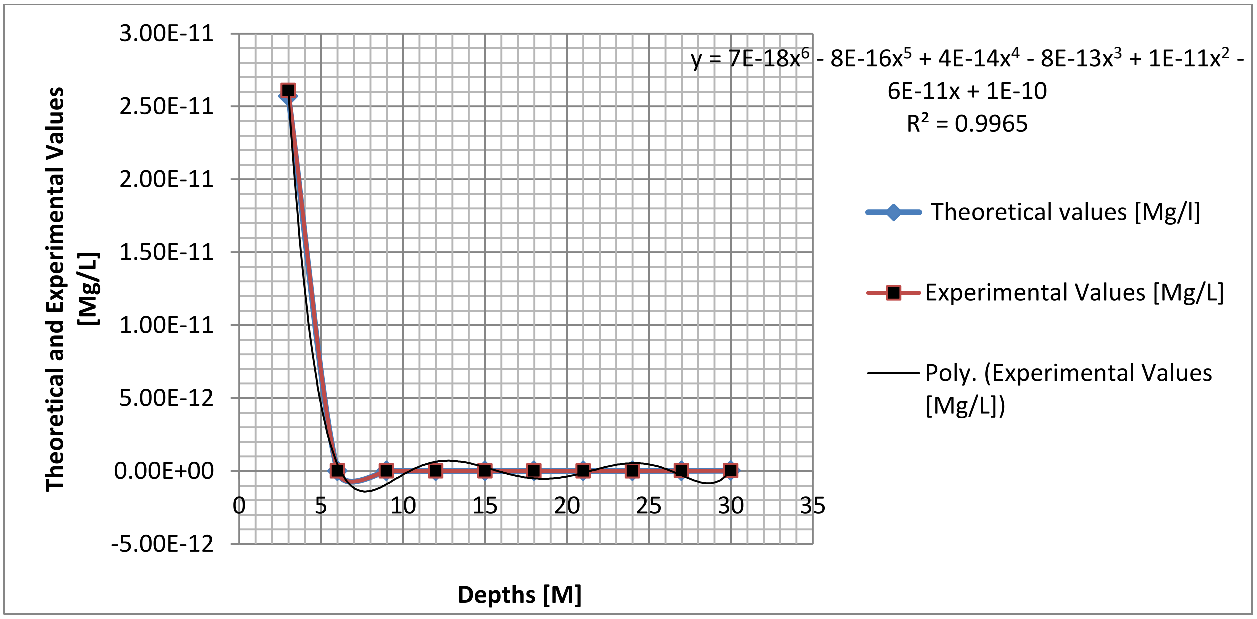

Figure: 10 Comparison of Theoretical and experimental values of Enteromobacter at Different Depths

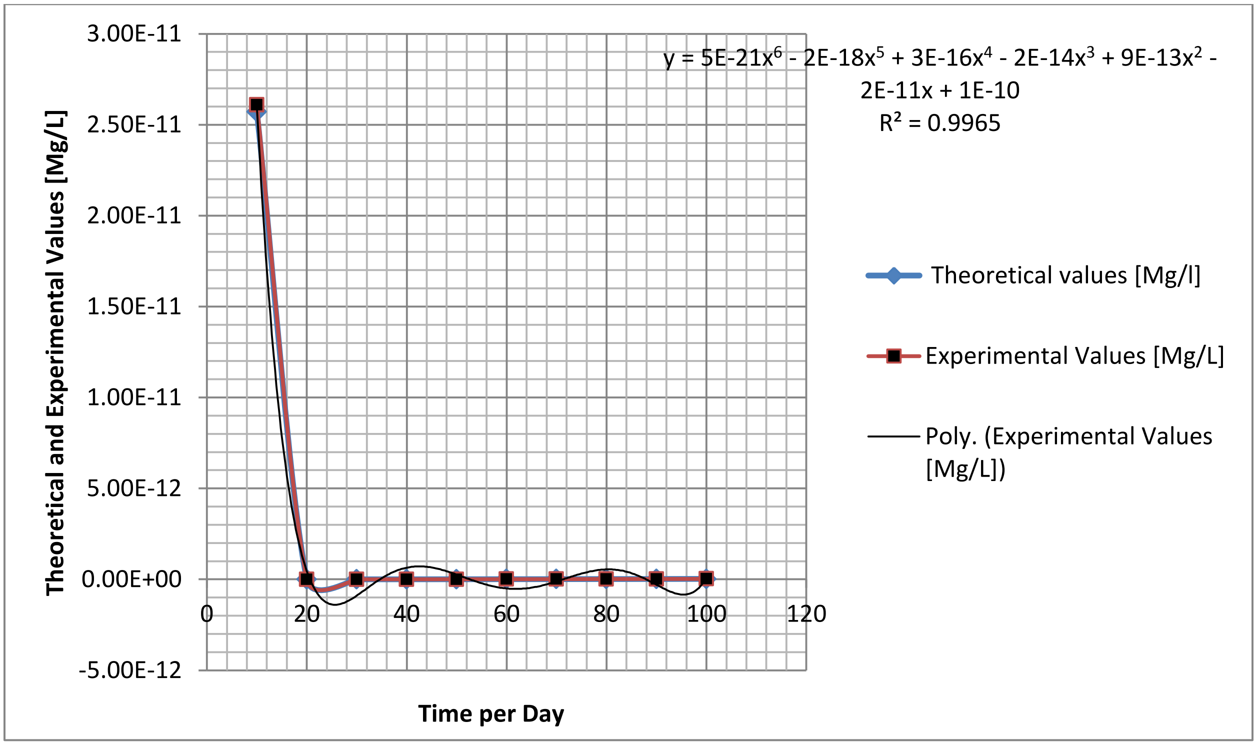

Figure: 11Comparison of Theoretical and experimental values of Enteromobacter at Different Time

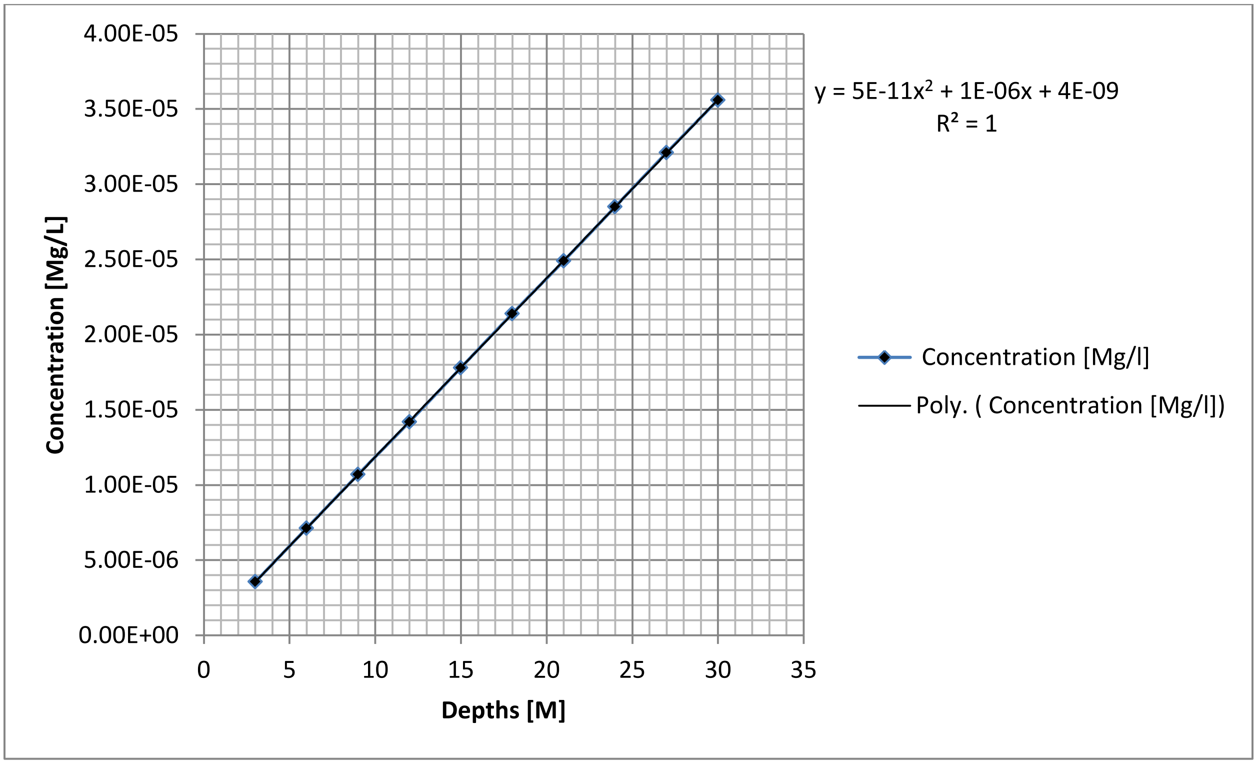

Figure: 12 concentration of the Enteromobacter at Different Depths

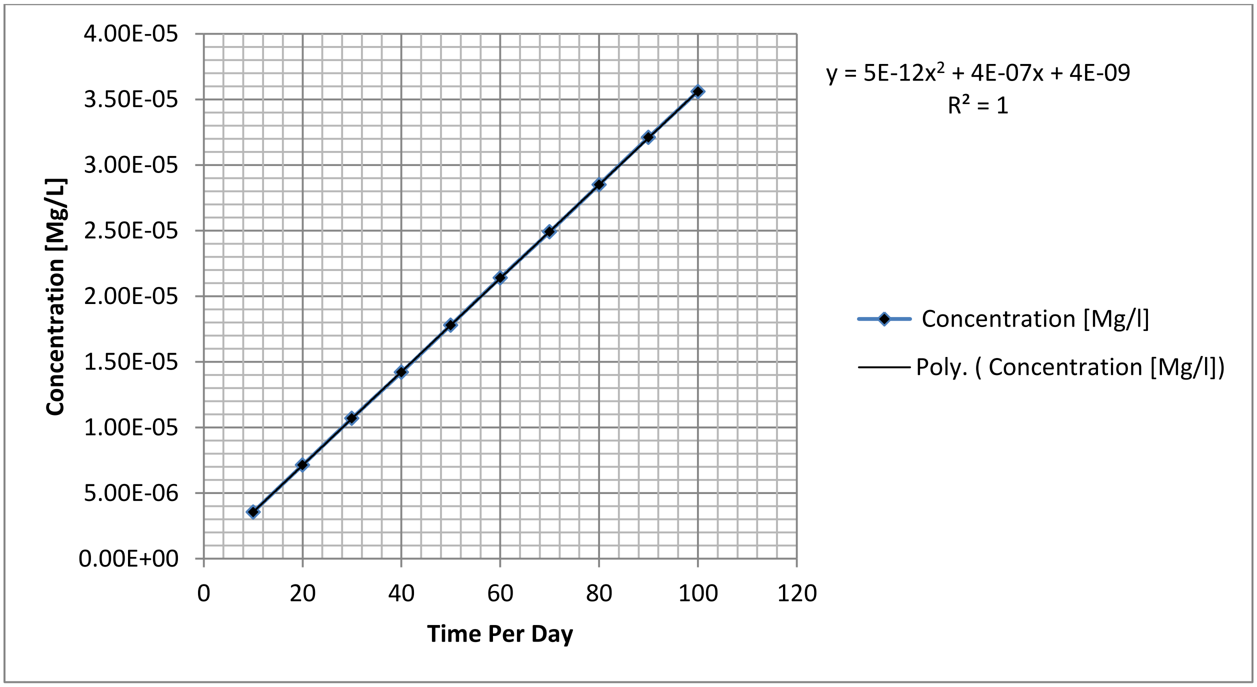

Figure: 13 concentration of the Enteromobacter at Different Depths

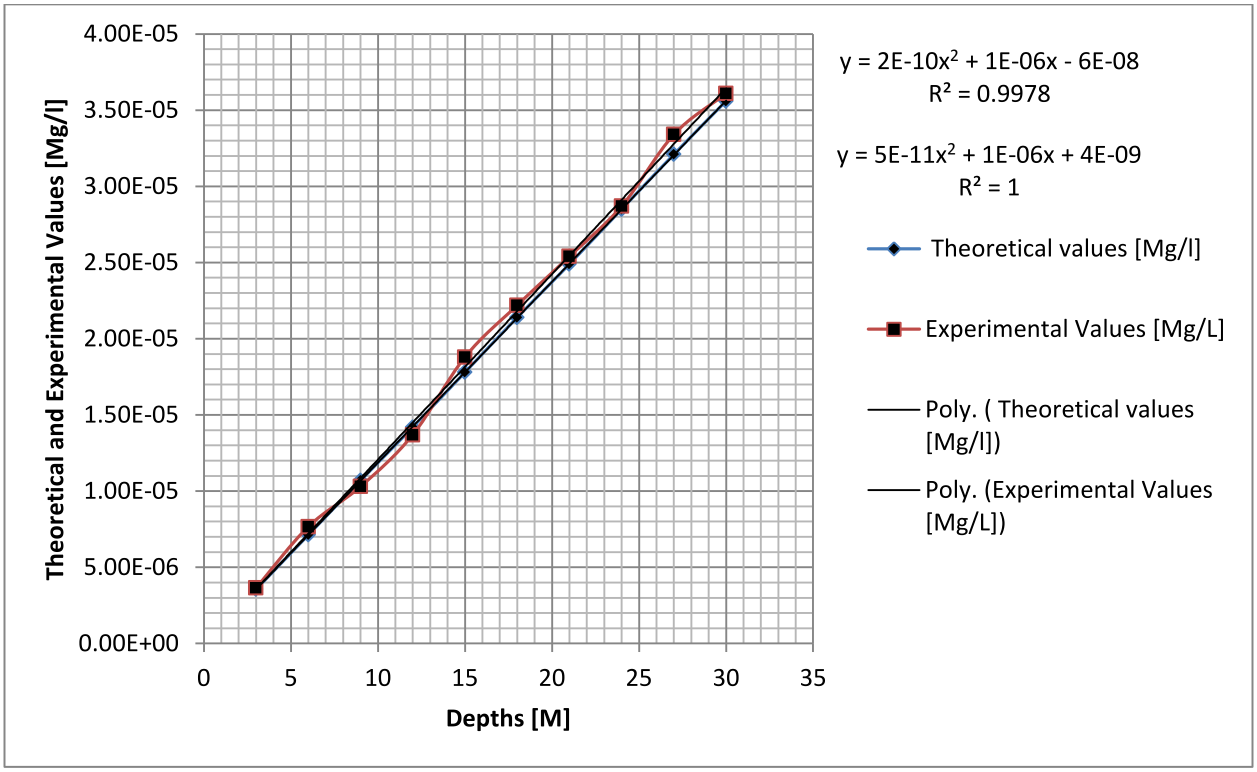

Figure: 14 Comparison of Theoretical and experimental values of Enteromobacter at Different Time

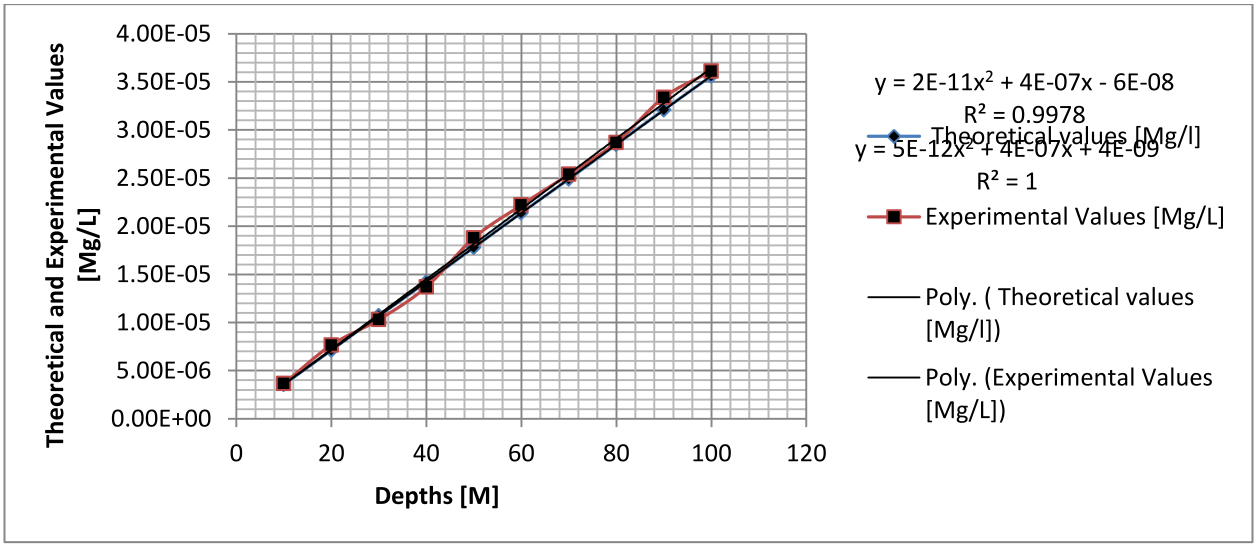

Figure: 15 Comparison of Theoretical and experimental values of Enteromobacter at Different Time

Figure one to four presented the following conditions; the exponential phase experiences the following reactions, through the formations monitored by simulating the developed model, considering those areas where porosity and void ratios are homogeneous. These were reflected on the stated figure that express very low concentration , these conditions found in figure one to four are influenced by the stated high influenced predominant formation characteristics, it can also develop variation in other locations, high to low concentration were found in some figures, the theoretical values were from the simulated model. Different experience were observed in figure eights thus were very high concentration of the contaminant were recorded, the expression from the figures shows the influences from low void ratio that may have deposited in some location or region resulting to high accumulation. The microbes in those formation are reflecting in the generated results from figure eight, similar condition were recorded from figure twelve to fifteen as the variation of formation characteristics including deposition of some faviourably minerals increase the concentration of the microbes in the study area. The expression from theoretical values at constant and different concentration were compared with experimental values, both parameters developed best fit, this expression from the developed model simulated express the behaviour of the transport system of the microbes. The developed model simulated has been validated through the generated theoretical data compared with experimental values, the migration and deposition of Enteromobacter model has express the rate of the contaminant developing variations at various conditions considered in the developed model for the study.

4. Conclusion

The developed model has expressed it behaviour through the simulated parameters for the study, the reflection from the strata are from the derived model that were simulate to express the deposition of the microbes at various formation, the developed model simulated at various condition were done with different parameters, the generated theoretical values from the simulation determined the rate of concentration at different conditions, these were reflected on the system through the variation deposition of the contaminant in the strata. The concentration were also found to be influenced by the rate of variation deposition from formation characteristics in the system, from the simulation results, the rate of concentration expressed exponential phase at different contaminant level, some area rate of concentration were very low that may be harmless to ground water aquifers while some deposition are very high as it is expressed in the figure, the developed model simulated results were compared with experimental values, both parameters developed best fit , these has validated the developed model for the study, expert will be apply the model to monitor the rate of Enteromobacter in the study area.

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