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Research article

MODELING AND SIMULATION OF ENTEROBACTERIACEAE IN HOMOGENEOUS SILTY FORMATION PENETRATING UNCONFINED BED IN BAKANA RIVERS STATE OF NIGERIA

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Abstract

The deposition of enterobacteriaceae in soil and water environments is of serious concern to environmental health. Such condition has been on investigation for better solution through several risk assessment, but could not developed a conceptual frame work that can prevent this microbes out from contaminating soil and water environment, the rate of ill health has call for serious concern as numerous number of peoples has develop serious ill health from this sources, the deposition of enterobacteriaceae has cause lots of serious ill heath to human settlements, the increase of the microbes are base on the predominant high porosity deposition that has pressured the migration process in the formation, such unhealthy condition call for better option to prevent the deposition of this contaminant from the environments , mathematical modeling approach were found appropriate to developed model that will prevent the spread of this contaminant as well monitor the rate of concentration at very formation to aquiferous zone. The research developed system that produced model for the study, the model were simulated and it generated theoretical values compared with other experimental results, both parameters developed best fits that has validated the model, this concept will definitely be favuorable to experts in monitoring and evaluation of enterobacteriaceae migration in soil and water environments.

Keywords: modeling and simulation, enterobacteriaceae, silty formation and unconfined bed

1. Introduction

Development in modelling microbial processes in porous media is necessary to improving our thoughtful of how physical, chemical, and biological processes are attached in groundwater and their effect on groundwater- chemistry evolution, bioremediation, and the reactive transport of contaminants and bacteria (Ellyn et al 2000). Much of the emphasis to date has been on quantitative representations of either the kinetics of contaminant degradation or the physical (or physicochemical) processes that affect the transport of bacteria in porous media, primarily because these issues are more tractable to the microbiological and hydrologic transport fields. Consequently, most reactive transport models incorporate some of the major physical processes, and these processes have been the focus of numerous experimental and numerical modelling studies on colloid and biocolloid research. In contrast, the biological processes of growth/decay, chemotaxis, predation, physiological adaptation (survival), and adhesion or active detachment are characteristics of the bacterial population and by comparison have received little attention in field-scale hydrogeologic transport models. Although many researchers readily acknowledge the importance of growth processes in transport (Harvey et al. 1984; Hansberger et al. 1992; Tan et al. 1994), growth is often eliminated in column or field experiments of biocolloid transport (Champ and Schroeter 1988; Harvey et al. 1989, 1993; Bales et al. 1995 Ellyn et al 2000). Quantitative representations of microbial processes in saturated porous media are numerous; however, the coupling of these processes in dynamic contaminant systems is not well understood. Under oligotrophic (carbon-limiting) conditions in aquifers, microbial growth is limited and most of the biomass is associated with the solid phase (Harvey et al. 1984; Hirsch and Rades-Rohkohl 1988; Kölbel-Boelke et al. 1988; Godsy et al. 1992; Albrechtsen 1994 Ellyn et al 2000). In these growth-limited environments, physical processes likely dominate transport of that portion of the biomass in the aqueous phase. In contrast, in nutrient-rich environments, such as contaminated aquifers, field observations consistently indicate a higher level of biomass in the aqueous phase. In a contaminated portion of the Cape Cod aquifer in Massachusetts, USA, Harvey et al. (1984) report that the aqueous biomass increased by an order of magnitude, whereas the concentration on the sediments remained approximately the same. Harvey and Barber (1992) observed 130% of total biomass free-living in a sewage-contaminated plume; Godsy et al. (1992) note that 90% of total biomass in a creosote contaminated aquifer was attached, but 49% of (creosote-degrading) methanogens were in the aqueous phase. Likewise, at an in-situ bioremediation study at the Savannah River Site in Georgia, USA, the proportion of methanotrophs, which were stimulated to degrade chlorinated hydrocarbons, increased by as much as five orders of magnitude in the aqueous phase (USDOE 1993). These observations are consistent with specific recognition of growth-induced partitioning to the aqueous phase (Jenneman et al. 1985, 1986; Reynolds et al. 1989; Sharma et al. 1993). Such conditions indicate a greater propensity for transport of native microbes under natural hydraulic gradients or under pumping as part of an accelerated bioremediation strategy when growth is a factor (Ellyn et al 2000).

2. Governing equation

$$K\phi\frac{\partial c}{\partial t} = -KD\frac{\partial c}{\partial x} \quad \text{……..} \quad (1)$$

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

$$C_o = ZT \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

i.e. $$\frac{\partial^2 c}{\partial x^2} = XT^{11} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$\frac{\partial^2 c}{\partial x} = X^1 T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

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

$$K\phi XT^{11} = KD\,X^1 T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

i.e. $$K\phi \frac{T^{11}}{T} = KD\frac{X^1}{X} = -\lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Hence

$$K\phi \frac{T^1}{T} = \lambda^2 X = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

i.e. $$X^1 + \lambda^2 X = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

And

$$KDX^1 + \lambda^2 X = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

From (8) $$T = ACos\frac{\lambda}{\sqrt{K\phi}}t + BSin\frac{\lambda}{\sqrt{KD}}x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

And (3) give

$$X = C_o \ell^{\frac{-\lambda^2}{\sqrt{KD}}x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

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

$$Co_2 = \left(ACos\frac{\lambda}{\sqrt{K\phi}}t + BSin\frac{\lambda}{\sqrt{KD}}t\right) Co\,\ell^{\frac{-\lambda}{\sqrt{KD}}x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

Subject to equation (12) this condition so that we have

$$C_o = AC \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

$\therefore$ Equation (13) becomes

$$Co_2 = Co\,\ell^{\frac{-\lambda^2}{\sqrt{KD}}x}\ Cos\ \frac{\lambda}{\sqrt{K\phi}}t \qquad \text{.............................. (14)}$$

Again

$$\left.\frac{dc_2}{dt}\right|_{t\ =\ 0,\ B}^{\ =\ 0} x = 0$$

Equation (14) becomes

$$\frac{dc_2}{dt} = \frac{\lambda}{\sqrt{K\phi}}\ell^{\frac{-\lambda^2}{\sqrt{KD}}x}\ Sin\ \frac{\lambda}{\sqrt{K\phi}}t \qquad \text{.............................. (15)}$$

i.e. $0 = Sin\ \frac{\lambda}{\sqrt{K\phi}}0$

$\frac{C_o\lambda}{\sqrt{K\phi}} \neq 0$ Considering NKP

Which is the substrate utilization for microbial growth (population), so that

$$0 = \frac{-C_o\lambda}{\sqrt{K\phi}}Sin\ \frac{\lambda}{\sqrt{K\phi}}B \qquad \text{.............................. (16)}$$

$$\Rightarrow \frac{\lambda}{\sqrt{K}} = \frac{n\pi}{2}n = 1, 2, 3 \qquad \text{.............................. (17)}$$

$$\Rightarrow \lambda = \frac{n\pi\sqrt{K\phi}}{2} \qquad \text{.............................. (18)}$$

So that equation (27) becomes

$$Co_2 = Co\,\ell^{\frac{-n^2\pi^2K\phi}{2KD}t}\ Cos\ \frac{n\pi}{2}\frac{\sqrt{KD}}{2\sqrt{KD}}x \qquad \text{.............................. (19)}$$

$$Co = Co\,\ell^{\frac{-n^2\pi^2K\phi}{2KD}t}\ Cos\ \frac{n\pi}{2}x \qquad \text{.............................. (20)}$$

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.

Table 1: Concentration of enterobacteriaceae at Different Depths

Depths [M]	Concentration[Mg/L]
1	688
2	275.38
3	619.62
4	1101.56
5	1721.18
6	2478.5
7	3373.52
8	4406.23
9	5576.64
10	6884.7

Table 2: Concentration of enterobacteriaceae at Different Time

Time [Per Day]	Concentration[Mg/L]
10	688
20	275.38
30	619.62
40	1101.56
50	1721.18
60	2478.5
70	3373.52
80	4406.23
90	5576.64
100	6884.7

Table 3: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Depths

Depths [M]	Theoretical values [Mg/l]	Experimental values [Mg/L]
1	688	691
2	275.38	285.43
3	619.62	629.44
4	1101.56	1106.74
5	1721.18	1743.23

6	**2478.5**	**2488.5**
7	**3373.52**	**3381.44**
8	**4406.23**	**4416.44**
9	**5576.64**	**5588.45**
10	**6884.7**	**6894.5**

Table 3: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Time

Time [Per Day]	Theoretical values [Mg/l]	Experimental values [Mg/L]
10	**688**	**691**
20	**275.38**	**285.43**
30	**619.62**	**629.44**
40	**1101.56**	**1106.74**
50	**1721.18**	**1743.23**
60	**2478.5**	**2488.5**
70	**3373.52**	**3381.44**
80	**4406.23**	**4416.44**
90	**5576.64**	**5588.45**
100	**6884.7**	**6894.5**

Table 4: Concentration of enterobacteriaceae at Different Depths

Depths [M]	Concentration[Mg/L]
2	**27.53**
4	**110.1**
6	**247.85**
8	**440.62**
10	**688.47**
12	**991.4**
14	**1349.4**
16	**1762.49**
18	**2230.65**
20	**2753.75**

Table 5: Concentration of enterobacteriaceae at Different Time

Time [Per Day]	Concentration[Mg/L]
2	**27.53**
4	**110.1**
6	**247.85**

8	**440.62**
10	**688.47**
12	**991.4**
14	**1349.4**
16	**1762.49**
18	**2230.65**
20	**2753.75**

Table 6: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Depths

Depth [M]	Theoretical values [Mg/l]	Experimental values [Mg/L]
2	**27.53**	**29.44**
4	**110.1**	**114.21**
6	**247.85**	**255.44**
8	**440.62**	**467.45**
10	**688.47**	**666.22**
12	**991.4**	**956.45**
14	**1349.4**	**1356.3**
16	**1762.49**	**1865.45**
18	**2230.65**	**2311.23**
20	**2753.75**	**2789.45**

Table 7: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Time

Time [M]	Theoretical values [Mg/l]	Experimental values [Mg/L]
2	**27.53**	**29.44**
4	**110.1**	**114.21**
6	**247.85**	**255.44**
8	**440.62**	**467.45**
10	**688.47**	**666.22**
12	**991.4**	**956.45**
14	**1349.4**	**1356.3**
16	**1762.49**	**1865.45**
18	**2230.65**	**2311.23**
20	**2753.75**	**2789.45**

Table 8: Concentration of enterobacteriaceae at Different Depths

Depths [M]	Concentration[Mg/L]
1	**0.49**

2	**0.99**
3	**1.49**
4	**1.99**
5	**2.49**
6	**2.99**
7	**3.49**
8	**3.99**
9	**4.99**
10	**5.01**

Table 9: Concentration of enterobacteriaceae at Different Time

Time [Per Day]	**Concentration[Mg/L]**
10	**0.49**
20	**0.99**
30	**1.49**
40	**1.99**
50	**2.49**
60	**2.99**
70	**3.49**
80	**3.99**
90	**4.99**
100	**5.01**

Table 10: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Depths

Depth [M]	**Theoretical values [**Mg/l]	**Experimental values** [Mg/L]
2	**0.49**	**0.51**
4	**0.99**	**1.02**
6	**1.49**	**1.45**
8	**1.99**	**2.11**
10	**2.49**	**2.55**
12	**2.99**	**3.11**
14	**3.49**	**3.67**
16	**3.99**	**4.11**
18	**4.99**	**5.14**
20	**5.01**	**4.99**

Table 11: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Depths

Time [Per Day]	**Theoretical values [**Mg/l]	**Experimental values** [Mg/L]
10	**0.49**	**0.51**

20	**0.99**	**1.02**
30	**1.49**	**1.45**
40	**1.99**	**2.11**
50	**2.49**	**2.55**
60	**2.99**	**3.11**
70	**3.49**	**3.67**
80	**3.99**	**4.11**
90	**4.99**	**5.14**
100	**5.01**	**4.99**

Table 12: Concentration of enterobacteriaceae at Different Depths

Depths [M]	Concentration[Mg/L]
3	**1.49**
6	**2.99**
9	**4.99**
12	**5.99**
15	**7.99**
18	**8.99**
21	**10.49**
24	**11.99**
27	**13.49**
30	**14.99**

Table 13: Concentration of enterobacteriaceae at Different Time

Time [Per Day]	Concentration[Mg/L]
10	**1.49**
20	**2.99**
30	**4.99**
40	**5.99**
50	**7.99**
60	**8.99**
70	**10.49**
80	**11.99**
90	**13.49**
100	**14.99**

Table 14: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Depths

Depths [M]	Theoretical values [Mg/l]	Experimental values [Mg/L]
3	1.49	1.44
6	2.99	2.88
9	4.99	4.88
12	5.99	6.11
15	7.99	8.14
18	8.99	8.77
21	10.49	10.66
24	11.99	12.11
27	13.49	13.55
30	14.99	15.11

Table 15: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Depths

Time [Per Day]	Theoretical values [Mg/l]	Experimental values [Mg/L]
10	1.49	1.44
20	2.99	2.88
30	4.99	4.88
40	5.99	6.11
50	7.99	8.14
60	8.99	8.77
70	10.49	10.66
80	11.99	12.11
90	13.49	13.55
100	14.99	15.11

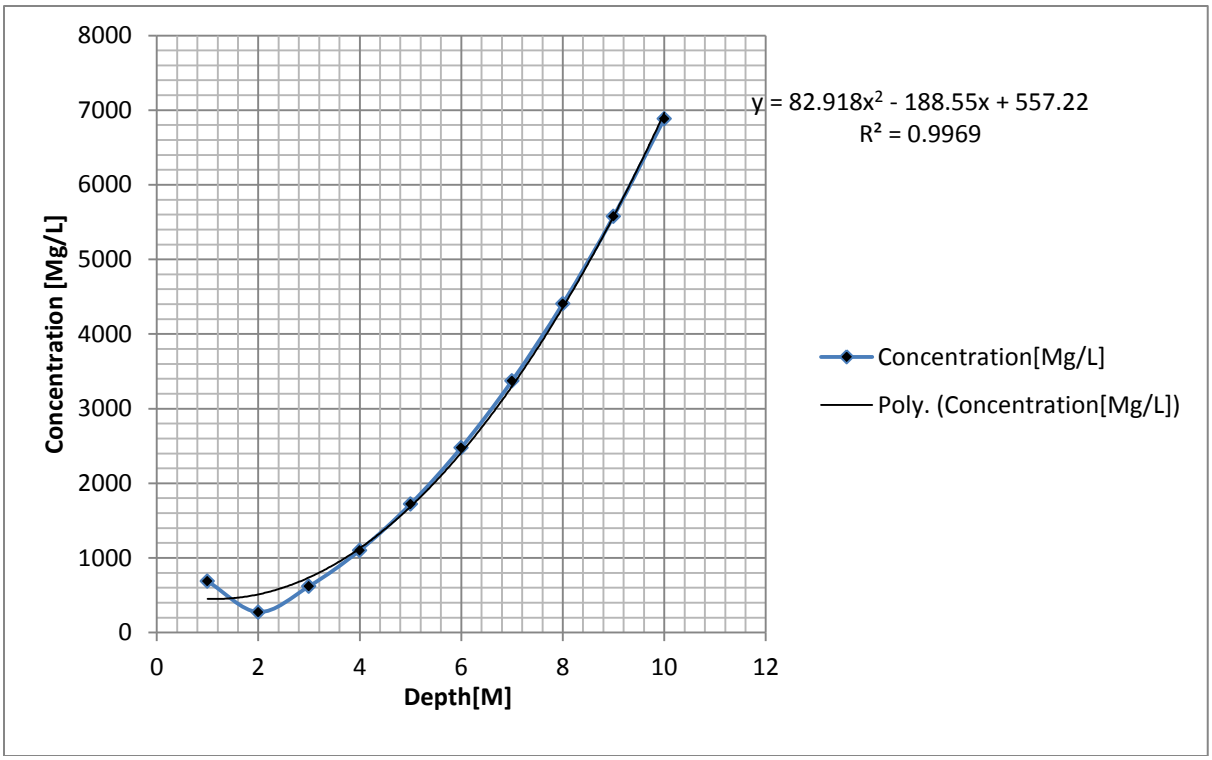

Figure 1: Concentration of enterobacteriaceae at Different Depths

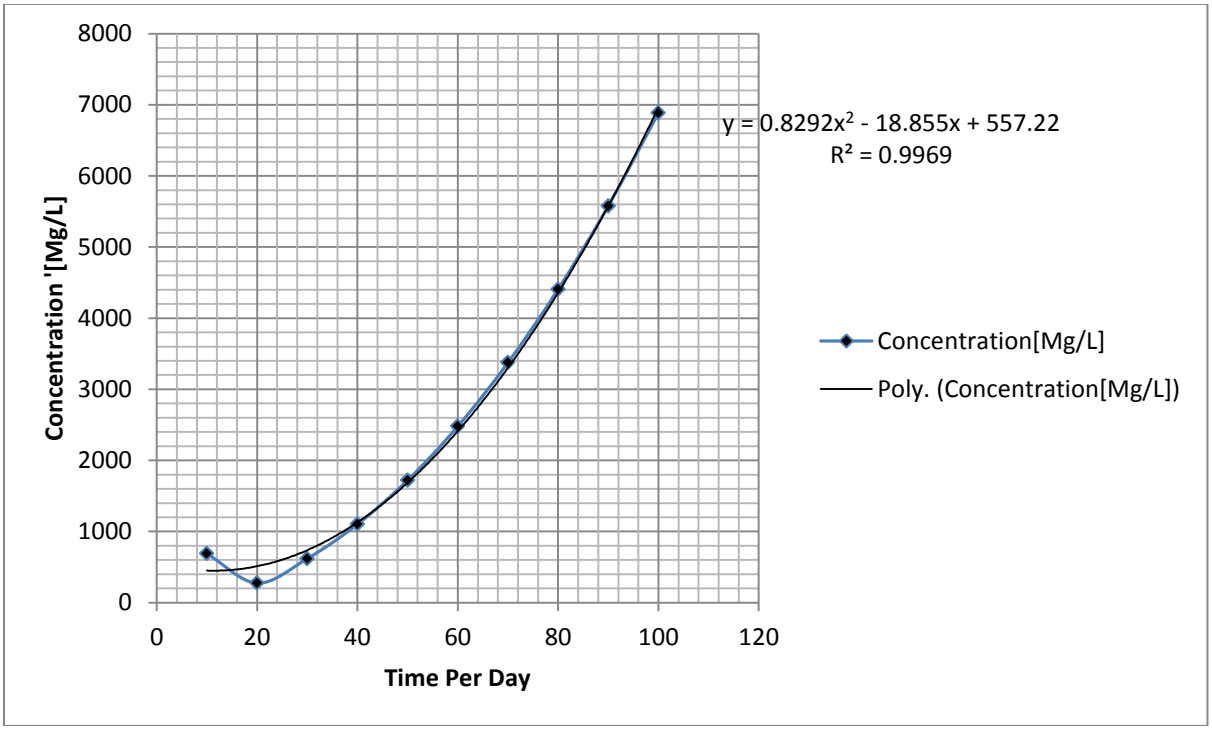

Figure 2: Concentration of enterobacteriaceae at Different Depths

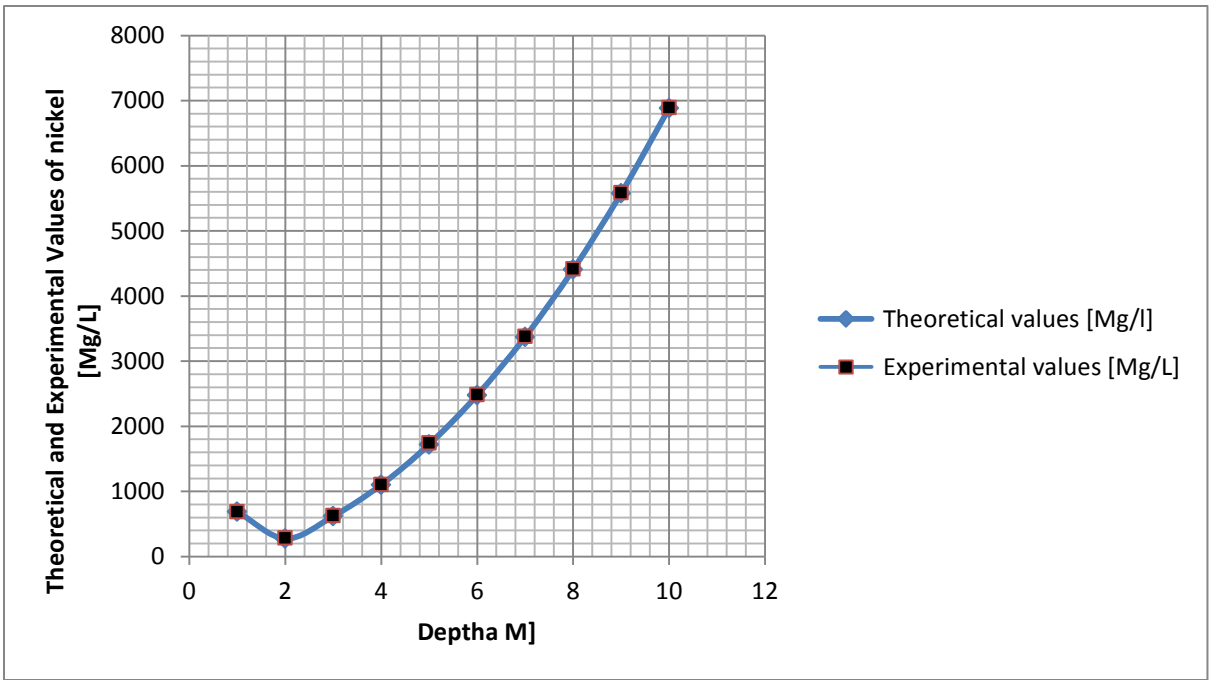

Figure 3: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Depths

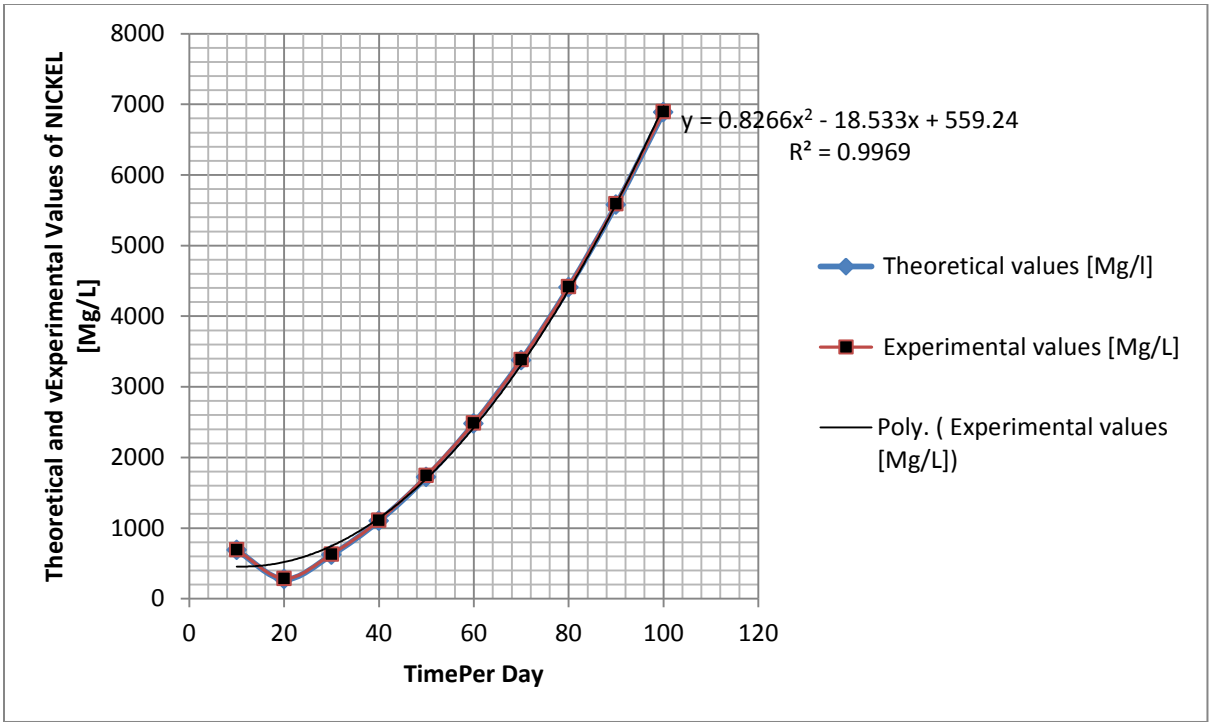

Figure 4: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Time

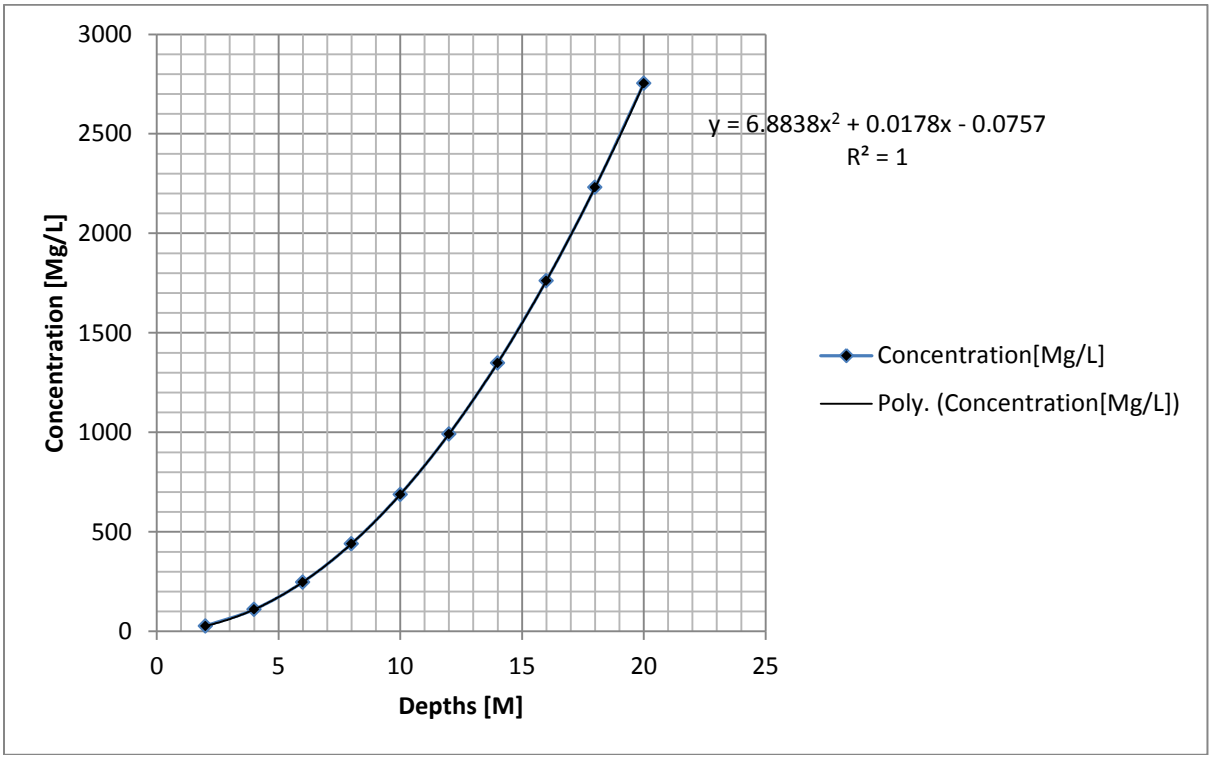

Figure 5: Concentration of enterobacteriaceae at Different Depths

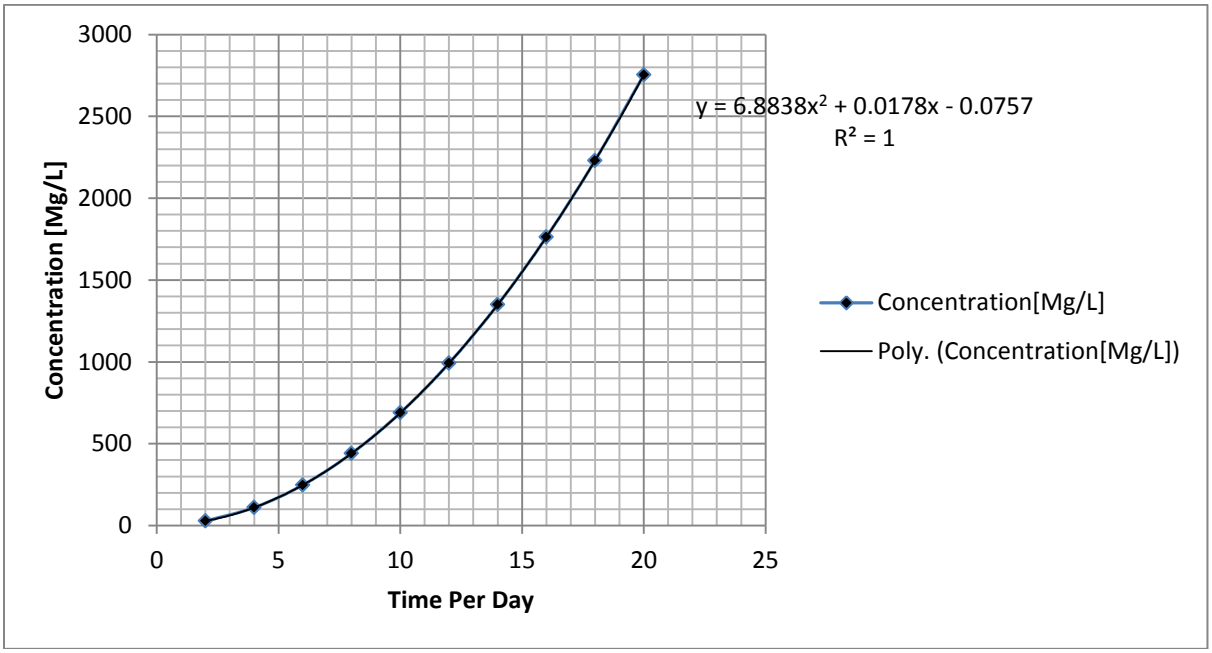

Figure 6: Concentration of enterobacteriaceae at Different Depths

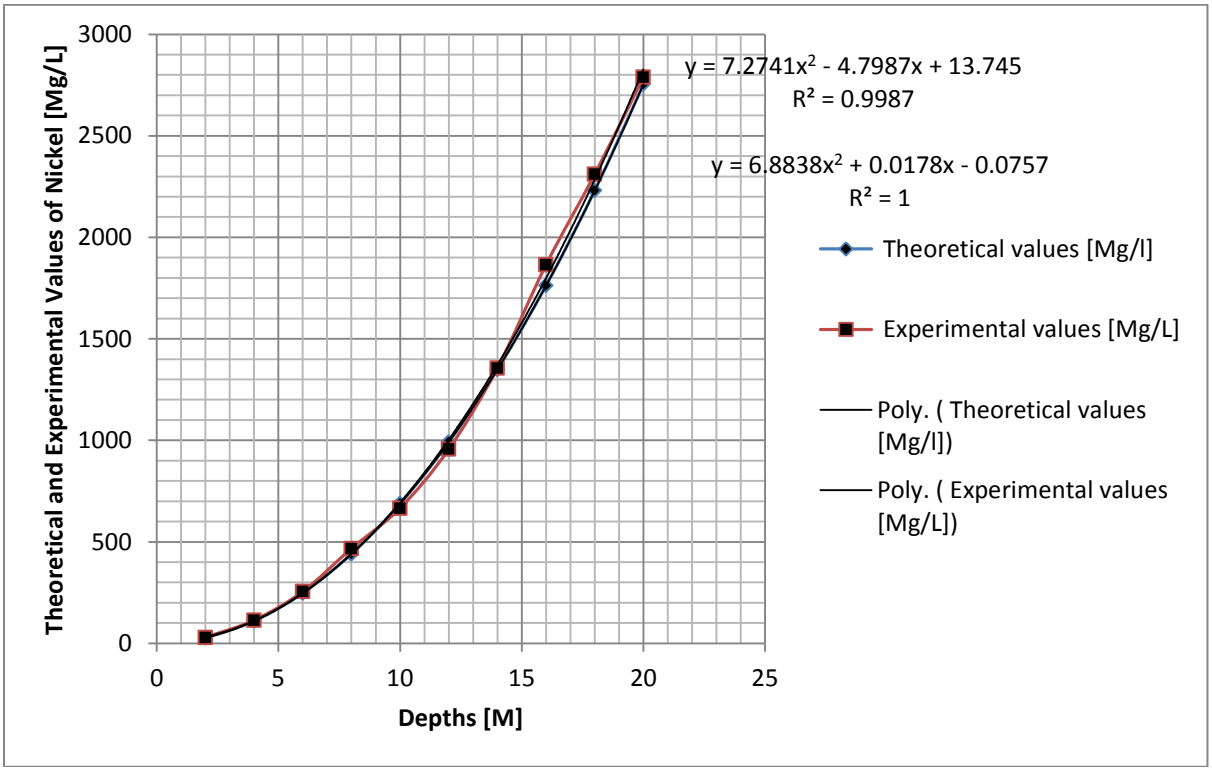

Figure 7: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Depths

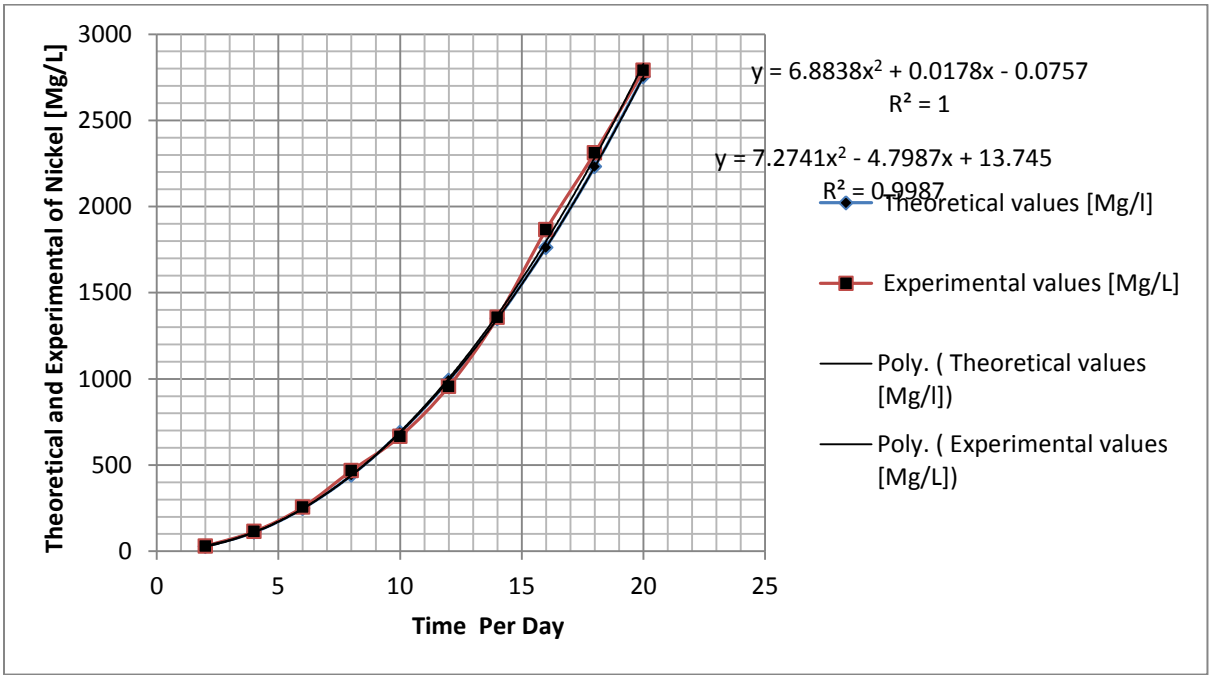

Figure 8: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Time

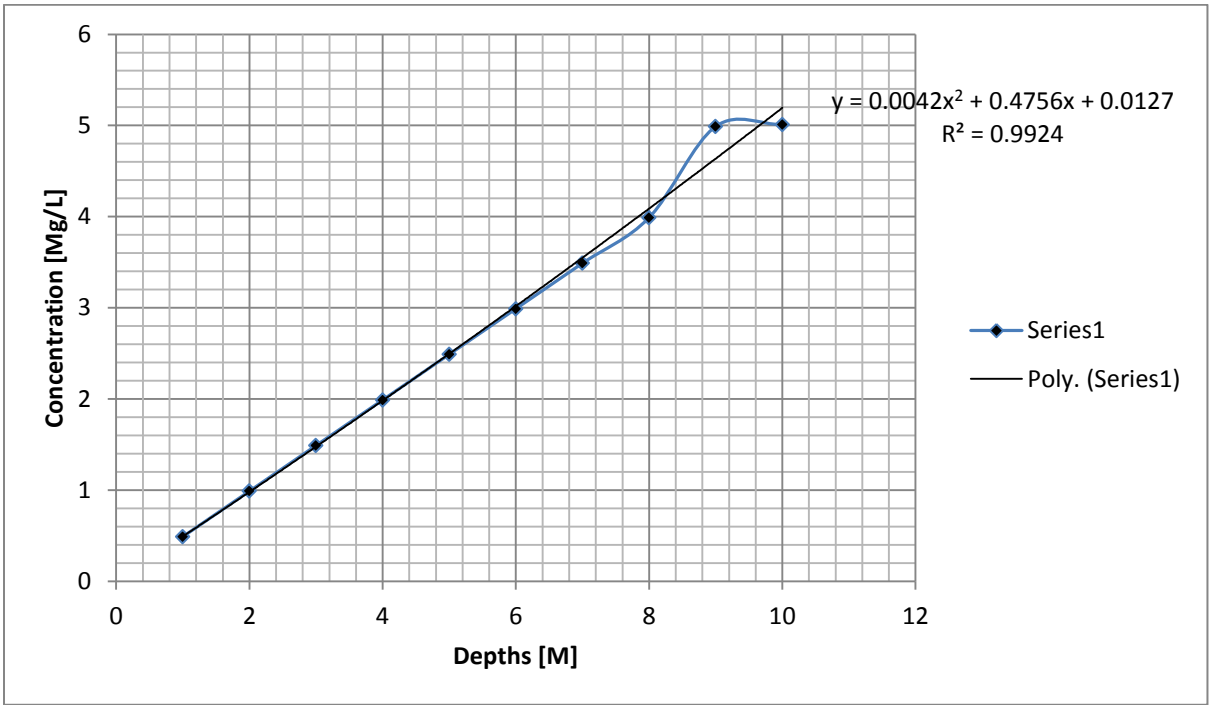

Figure 9: Concentration of enterobacteriaceae at Different Depths

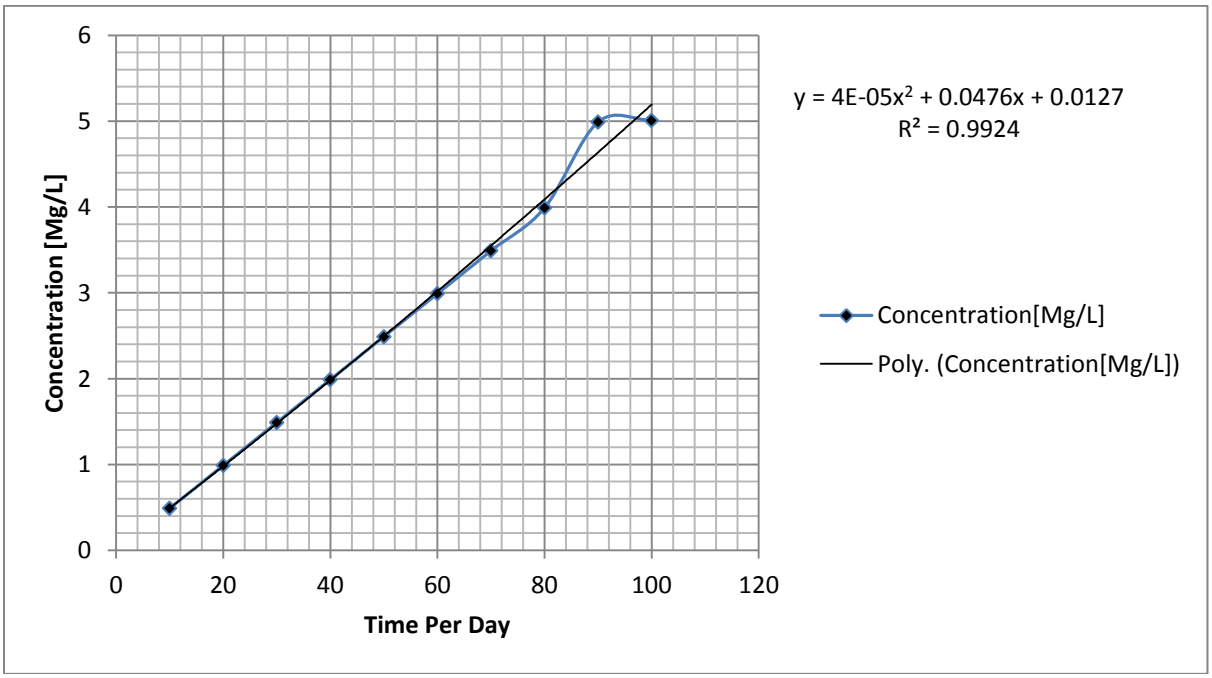

Figure 10: Concentration of enterobacteriaceae at Different Time

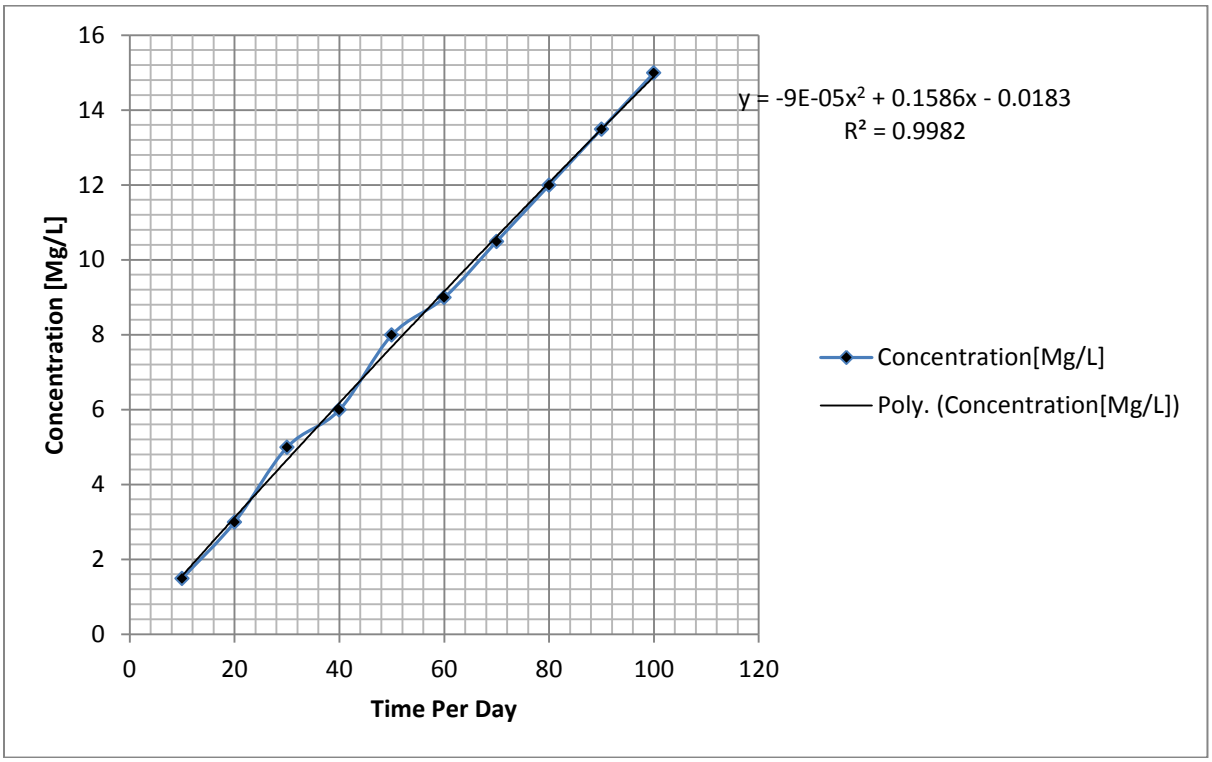

Figure 11: Concentration of enterobacteriaceae at Different Time

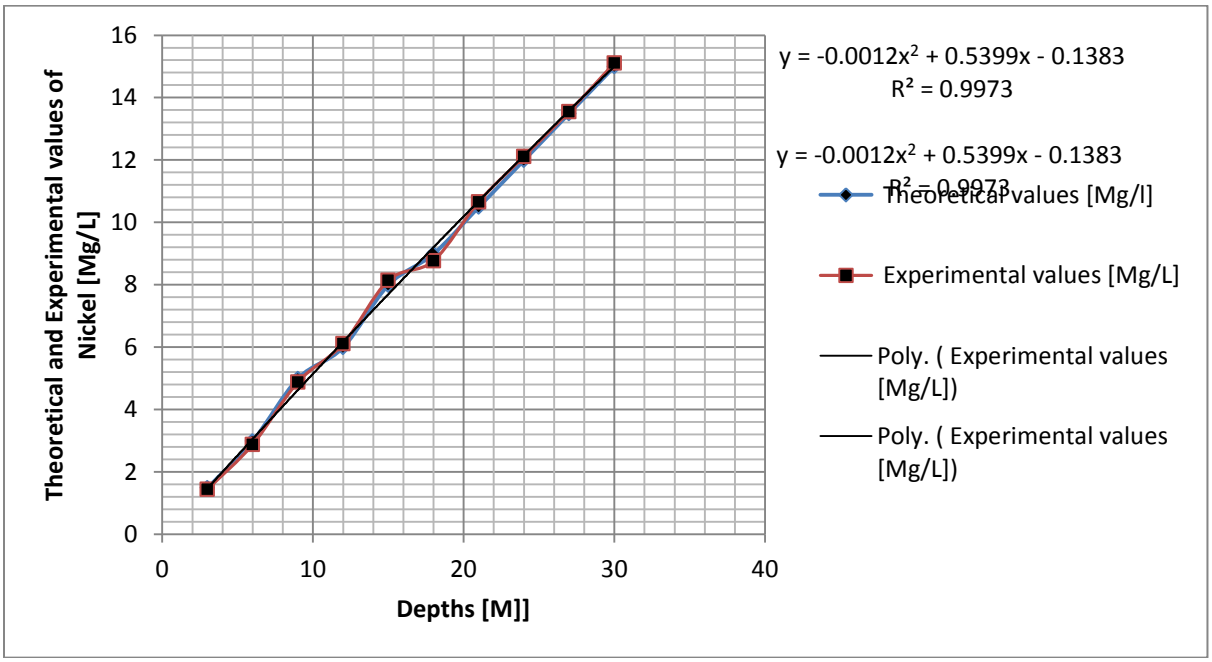

Figure 12: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Time

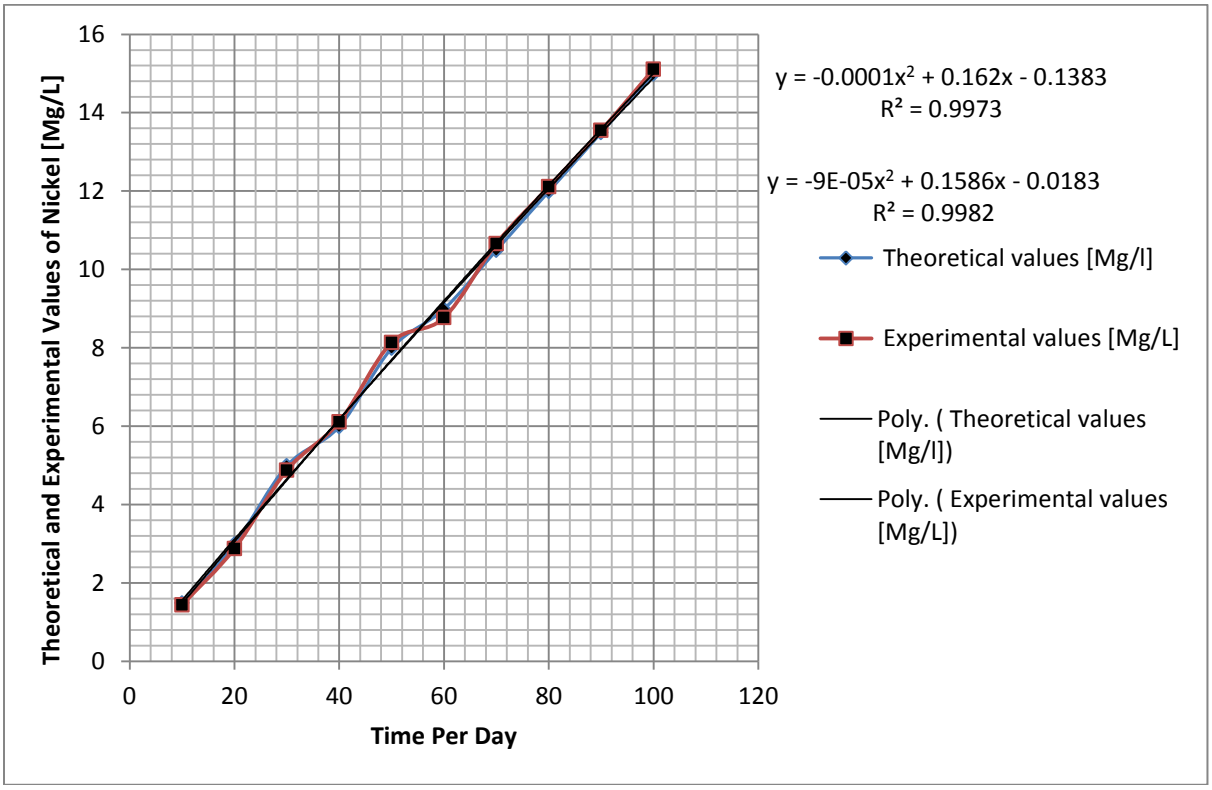

Figure 12: Comparison of Theoretical and Experimental Values of enterobacteriaceae concentration at Different Time

The presented figure [1-12] shows that the microbes are in exponential phase, several situations are known to have caused the fluctuation of the concentration in the transport system but porosity is predominantly deposited in the environment, therefore the issue of migration will definitely depend on the rate of porosity degree in the study area. Similar condition are found to pressure the deposition of the microbes, the figures express it concentration from the simulation results in exponential phase, the behaviour of Enterobacteriaceae are confirm to been pressured by predominant degree of porosity of the soil, homogeneous deposition of the strata and degree of porosity has been observed in the strata, but the concentration may experiences slight variation grain size that may be insignificant in general evaluation, even if it generate slight fluctuation of porosity and concentration of enterobacteriaceae, the predominant deposition of this microbes in the study area has cause lots of ill health as it is expressed in the figures, high percentage of concentration were found in some area where there is regeneration of biological waste, since high degree of porosity are predominant, fast migration of enterobacteriaceae generates ground water pollution, generating thousand of death every year, risk assessment carried out expressed the rate migration, but permanent solution were not available , therefore mathematical model were found appropriate to monitor the level of deposition in the formation, the structure of the soil were monitored in other to determine its rates of concentration in the study area , since porosity were found to deposit highest degree of all other formation characteristics, it has pressure the migration of the microbes to an optimum level, variation of deposition were also found in the study, the deposition of microelement pressure some the concentration to deposition higher than others, despite their

exponential condition there rate of concentration varies under the influences of variation of microelements in the formations.

4. Conclusion

The behaviour of enterobacteriaceae has been critically analyzed in the study area, such condition has been found imperative since lots of unhealthy condition has reported to generated lots of death in the study area, several investigation has been carried out, but could not defined any better solution to engineer this contaminants out in soil and water environments, it has been found from other experts that migration of the pollutant are from several source, but the transport of the microbes are determined by the level of stratification, base on geological setting in the study location. The capability of microbes to migrate through soil increases the likelihood of water pollution. The possibility of contamination will boost additional if microorganisms have the capability to survive for lengthy periods of time, microbes were found to migrate in groundwater faster than a chemical tracer under the same flow conditions. This demonstrates that some mechanism(s) exist to allow preferential movement of microorganisms in addition to those of transport chemical tracers. A variety of transport and attenuation processes may modulate and organize microbial transport through soil. These include advection, dispersion, filtration, and adsorption/desorption, sedimentation, growth, death, and chemotaxis. Microorganisms migrating into and through soil from sources on the land surface may cause a serious threat to both ground and surface waters. It has been approximate that microbes can migrate significant distances in the field. Results from various studies suggested that preferential flow through micropores, worm holes, racks, and fractures is the main reason for such observations. However, a quantitative representation of this phenomenon has not been provided. Finally the micropores in structural deposition of the formation are the sources of enterobacteriaceae migration within the silty formation penetrating unconfined aquiferous zone in the study location. The predominant level of porosity in such deltaic formation developed increase in migration of enterobacteriaceae in the study area.

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