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Predictive Models to Evaluate Plug Flow Infiltration of Nitrobacter Transport in Saline Environment

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Abstract: *The depositions of Nitrobacter have been the subject of concern in soil and water environment. Regeneration of Nitrobacter contributes in the deterioration of the water quality in coastal environment. The study was assessed to monitor the rate of Nitrobacter transport to phreatic zones in a saline environment. The investigation showed that the ground water aquiferous zone develop heterogeneous setting which deposits shallow and deep Phreatic beds. The study expressed was predominantly influenced by saline and other mineral deposits in the formation, but with slight influences from alluvium depositions. This implies that the formation characteristic has more effect on the rate of Nitrobacter concentration in some stratum. Fluctuations in various locations were observed through the effect from the structural setting of the formation and exponential phase of transport were observed to be predominant. The system developed governing equations that were derived to generate the expressed model that predicted the behaviour of Nitrobacter in the formation. The models were simulated to produce theoretical values which were compared with other measured values. Both parameters developed favourable fits validating the model. The measured concentration of the Nitrobacter increased to the optimum value of 7.96E-02 (mg/l) within 100days and 0.073E-03 (mg/l) at 30m depth*
Keywords: *Evaluate, Nitrobacter, Plug flow phase, Saline environment and transport*

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I. INTRODUCTION

The effectiveness of microbes to be converted as absorbed soil carbon into microbial biomass has been called the microbial growth efficiency (Y), carbon-use efficiency, or substrate-use effectiveness. This physiological features of the microbial biomass powerfully pressure overall soil unrefined carbon (SOC). Moreso, the mineral budgets such as carbon sequestration are found in the soil environment [1], [2], [3]. Since nutrient ratios in microbial biomass differ over comparatively narrow ranges, Y also contributes to regulation of nitrogen and other nutrients. Mineralization and immobilization in soils express measurements of microbial growth efficiency in soil span surprisingly over a wide range, from 0.14 to 0.77 [4], [5], [6]. Despite the high variability of this integrative trait and its importance in influencing organic matter turnover including nutrient availability, we have limited understanding of how environmental variables influence growth efficiency [3], [5]. The size and structure of the soil microbial population plays a role in the primary making of plant carbon (C) portion, rhizosphere activity, and litter substrate superiority [7], [8], [9], [10] and it is also controlled through complex communications with plants [11], [12] [13]. Changes in atmospheric CO_2 concentration and nitrogen (N) deposition rates alter both the quality and quantity of plant carbon and underground plant litter inputs to soil [2], [8], [13]. This in turn can affect underground microbial society arrangement and function [4], [14], [15] considering that the mechanisms controlling underground carbon processes is useful in predicting future changes in soil carbon stores in response to climate and land-use change [16]. Altering root and coarse woody debris (CWD) inputs to soil is one method to examine the feedbacks between plants, microbes, and soil organic matter (SOM) dynamics [15], [10], [17], [18].

II. MATERIALS AND METHODS

Column experiments were performed using soil samples from several borehole locations. The soil samples were collected at intervals of 3m. A Nitrobacter solute was introduced at the top of the column and effluents from the lower end of the column were collected and analyzed for Nitrobacter. These effluents were collected at different days. This experiment were performed to compare with the theoretical values for model validation

1.1 Governing Equations

Using the deterministic modeling techniques by applying analytical solution, the governing equations for the study are expressed in Equation 1:

$$K \frac{\partial^2 c}{\partial t^2} = D \frac{\partial c}{\partial Z} - U\lambda \frac{\partial c}{\partial Z} \tag{1}$$

Where;

C	=	*Enterococci concentration*	*[ML-3]*
λ	=	*Saline concentration*	*[ML-3]*
K	=	*Permeability*	*[LT-1]*
U	=	*Velocity*	*[LT-1]*
T	=	*Time*	*[T]*
Z	=	*Depth*	*[L]*

Let $C = T, Z$

$$KT^{11}Z = DTZ^1 - U\lambda TZ^1 \tag{2}$$

$$K \frac{T^{11}}{T} = D\frac{Z^1}{Z} - U\lambda \frac{Z^1}{Z} \tag{3}$$

$$K \frac{T^{11}}{T} = \theta^2 \tag{4}$$

$$D \frac{Z^1}{Z} = \theta^2 \tag{5}$$

$$- U\lambda \frac{Z^1}{Z} = \theta^2 \tag{6}$$

$$\left[D - U\lambda\right]\frac{Z^1}{Z} = \theta^2 \tag{7}$$

$$K \frac{dc}{dt} = \theta^2 \tag{8}$$

$$K \frac{dc^2}{dt^2} = \theta^2 \tag{9}$$

$$D \frac{dc}{dZ} = \theta^2 \tag{10}$$

$$- U\lambda \frac{dc}{dZ} = \theta^2 \tag{11}$$

$$d^2 Z = \left[\frac{\theta^2}{K}\right] = dZ \tag{12}$$

$$\int d^2 = \int \frac{\theta^2}{K} dZ \tag{13}$$

$$dZ = \frac{\theta^2}{K} Z + C_1 \tag{14}$$

$$\int dZ - \int \frac{\theta^2}{K} Z \; dZ + C_1 \int dZ \tag{15}$$

$$Z = \frac{\theta^2}{K}\frac{Z^2}{2} + C_1 + C_2 \tag{16}$$

$$Z = \frac{\theta^2}{K}\frac{Z^2}{2} + C_{1^2} + C_2 \tag{17}$$

$$\boxed{Z = \frac{\theta^2}{K} Z^2 + C_{1^2} + C_2} \quad (18)$$

$$\Rightarrow \frac{\theta^2}{2K} Z^2 + C_{1^2} + C_2 = 0 \quad (19)$$

Therefore, the auxiliary equation is shown in Equation 20:

$$\frac{\theta^2}{2K} M_2 + C_2 M + C_2 = 0 \quad (20)$$

Applying quadratic expression, we have

$$M_{1^2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad (21)$$

$$M = \frac{-C_1 \sqrt{C^2 - 4\frac{(\theta^2)}{2K} C_2}}{2\frac{\theta^2}{K}} \quad (22)$$

$$M_1 = \frac{- + C_1 \sqrt{C^2 - 2C_2 \frac{\theta^2}{K}}}{2\frac{\theta^2}{K}} \quad (23)$$

$$M_2 = \frac{-C - \sqrt{C_1^{\,2} - 2C_2 \frac{\theta^2}{K}}}{2\frac{\theta^2}{K}} \quad (24)$$

Assuming this discriminate is complex, therefore equation (23) and (24) can be written as:

$$C[T,Z] = F1\,Cos\,M_1 t + F2\,Sin\,M_2 Z \quad (25)$$

But if $t = \frac{d}{v}$ and $Z = v \cdot t$

The expressed model can be written as:

$$C[T,Z] = F1\,Cos\,M_1 \frac{d}{v} + F2\,Sin\,M_2 V \cdot t \quad (26)$$

III. RESULTS

The results of Nitrobacter concentrations at different depth and time are presented in Tables 1 to 8.

Table 1: Theoretical vales of Nitrobacter at Different Depth

Depth [m]	Theoretical Values Conc. [Mg/L]
3	1.52E-04
6	2.65E-04
9	4.18E-04
12	5.61E-04
15	7.34E-04
18	8.76E-04
21	9.59E-04
24	1.24E-03
27	1.38E-03
30	1.52E-03

Table 2: Theoretical vales of Nitrobacter at Different Time

Time per day	Theoretical Values Conc. [Mg/L]
10	1.62E-04
20	2.55E-04
30	4.38E-04
40	5.81E-04
50	7.64E-04
60	8.76E-04
70	9.79E-04

80	1.34E-03
90	1.38E-03
100	1.52E-03

Table 3: Theoretical and Measured values of Nitrobacter Concentration at Different depth

Depth [m]	Theoretical Values Conc. [Mg/L]	Measured Values[Mg/L]
3	1.62E-04	1.89E-04
6	2.55E-04	3.32E-04
9	4.38E-04	4.62E-04
12	5.81E-04	6.42E-04
15	7.64E-04	7.41E-04
18	8.76E-04	9.42E-04
21	9.79E-04	1.36E-03
24	1.34E-03	1.47E-03
27	1.38E-03	1.51E-03
30	1.52E-03	1.54E-03

Table 4: Theoretical and Measured values of Nitrobacter Concentration at Different Time

Time per day	Theoretical Values Conc. [Mg/L]	Measured Values[Mg/L]
10	Theoretical Values Conc.	1.32E-04
20	1.62E-04	2.42E-04
30	2.55E-04	3.52E-04
40	4.38E-04	4.62E-04
50	5.81E-04	5.32E-04
60	7.64E-04	6.37E-04
70	8.76E-04	7.35E-04
80	9.79E-04	8.18E-04
90	1.34E-03	9.27E-04
100	1.38E-03	1.22E-03

Table 5: Theoretical vales of Nitrobacter at Different Depth

Depth [m]	Theoretical Values Conc. [Mg/L]
3	8.39E-03
6	0.018
9	0.029
12	0.035
15	0.048
18	0.06
21	0.062
24	0.072
27	0.082
30	0.091

Table 6: Theoretical vales of Nitrobacter at Different Time

Time per day	Theoretical Values Conc. [Mg/L]
10	8.59E-03
20	0.026
30	0.035
40	0.043
50	0.051
60	0.06
70	0.072
80	0.082
90	0.084
100	0.092

Table 7: Theoretical and Measured values of Nitrobacter Concentration at Different depth

Depth [m]	Theoretical Values Conc. [Mg/L]	Measured Values Conc. [Mg/L]
3	8.59E-03	6.73E-03
6	0.026	0.032
9	0.035	0.036
12	0.043	0.039
15	0.051	0.043
18	0.06	0.045
21	0.072	0.052

24	0.082	0.064
27	0.084	0.067
30	0.092	0.073

Table 8: Theoretical and Measured values of Nitrobacter Concentration at Different Time

Time per day	Theoretical Values Conc. [Mg/L]	Measured Values Conc. [Mg/L]
10	8.34E-03	7.93E-03
20	0.026	1.86E-02
30	0.029	2.45E-02
40	0.037	3.22E-02
50	0.047	3.88E-02
60	0.055	5.45E-02
70	0.064	5.74E-02
80	0.073	6.73E-02
90	0.088	7.46E-02
100	0.097	7.96E-02

The graphical representation of Nitrobacter concentration at different depth and time are shown in Figures 1 to 8.

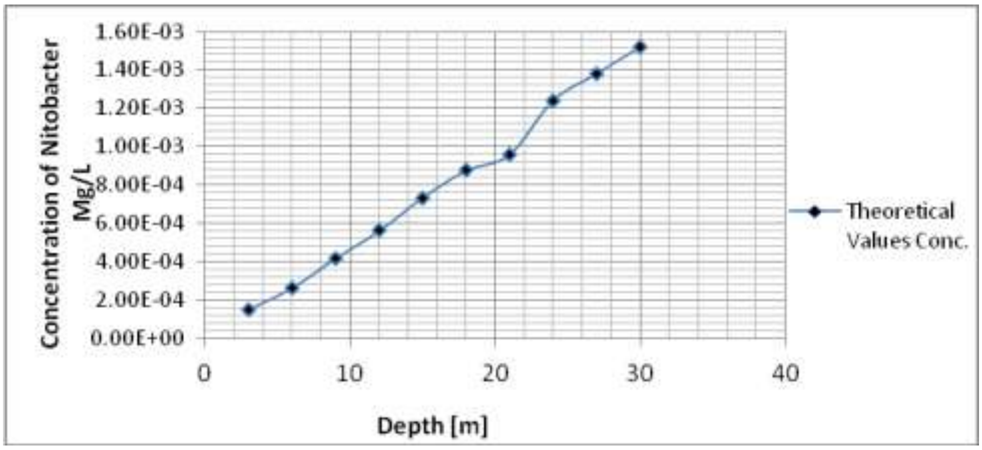

Figure 1: Theoretical vales of Nitrobacter at Different Depth

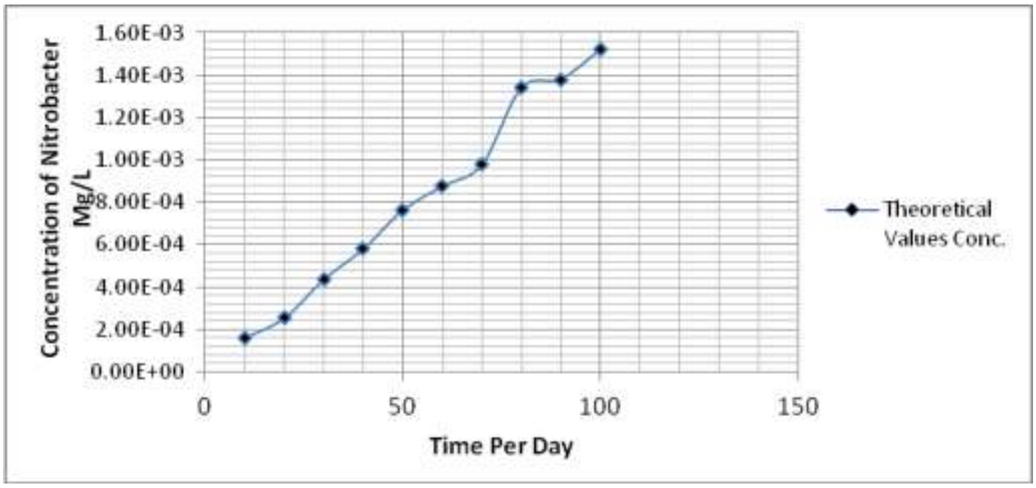

Figure 2: Theoretical vales of Nitrobacter at Different Time

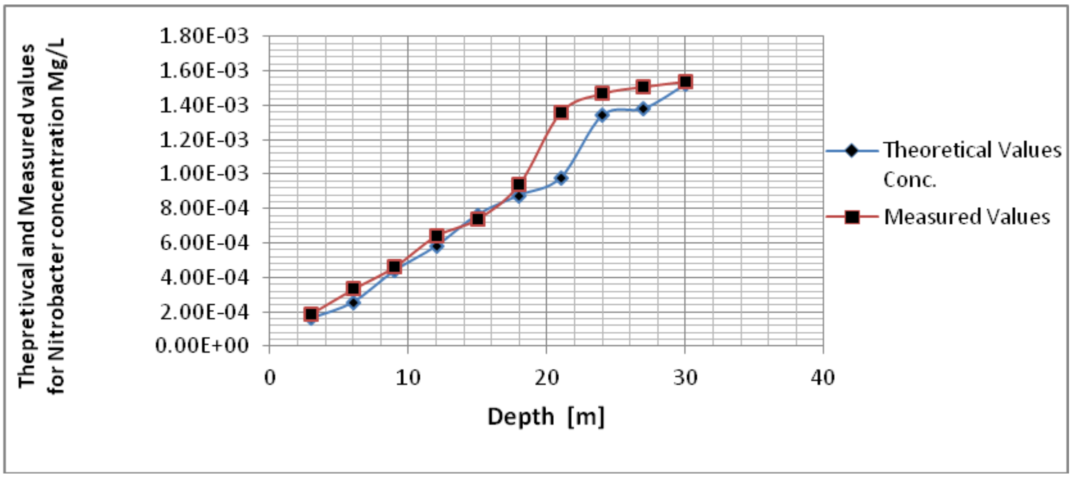

Figure 3: Theoretical and Measured values of Nitrobacter Concentration at Different Depth

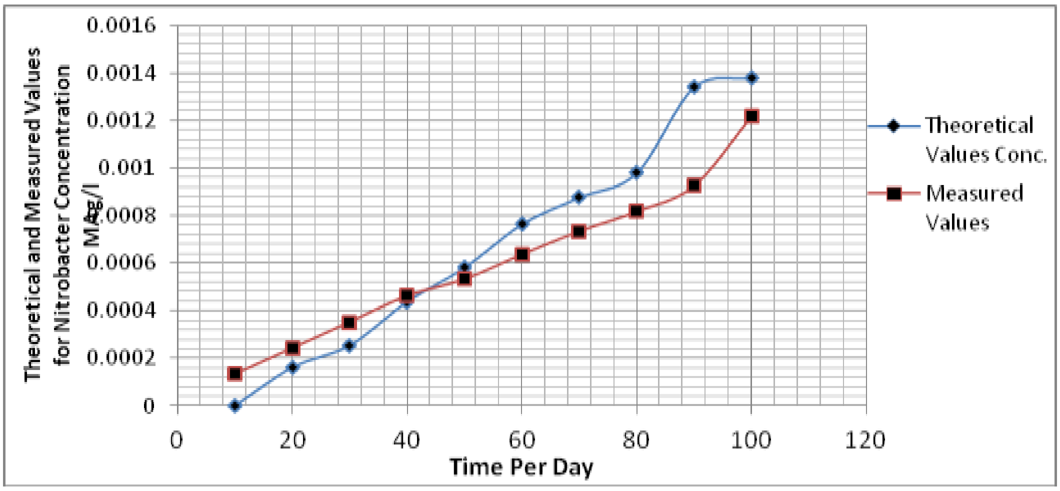

Figure 4: Theoretical and Measured values of Nitrobacter Concentration at Different Time

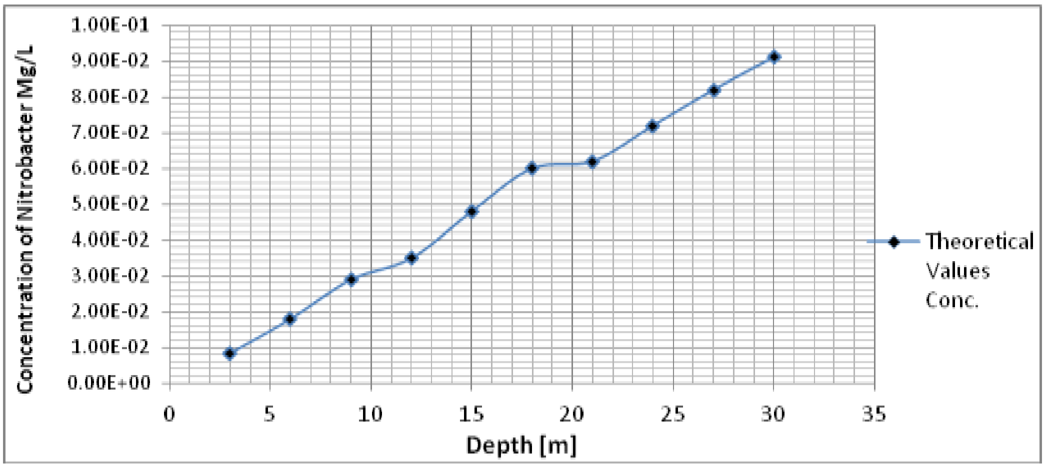

Figure 5: Theoretical vales of Nitrobacter at Different Depth

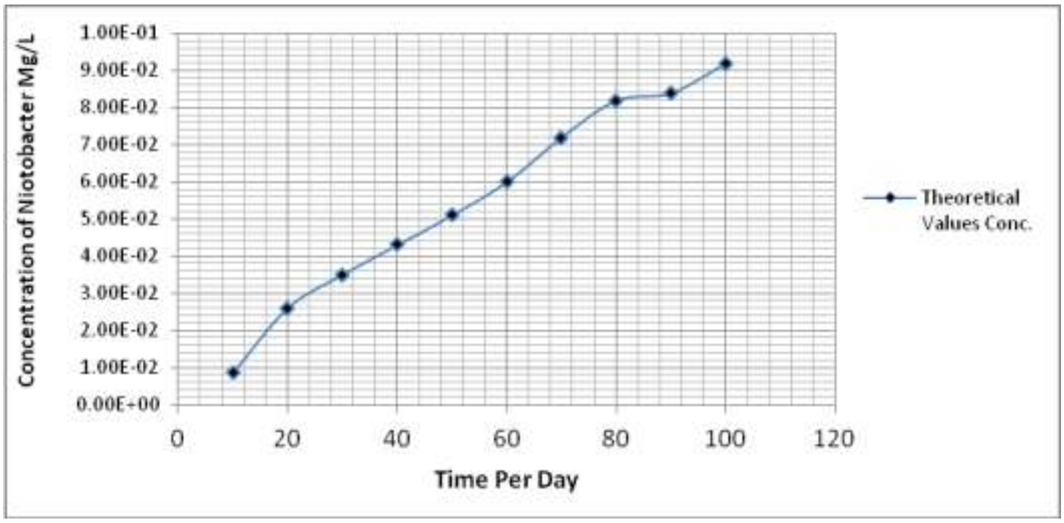

Figure 6: Theoretical vales of Nitrobacter at Different Time

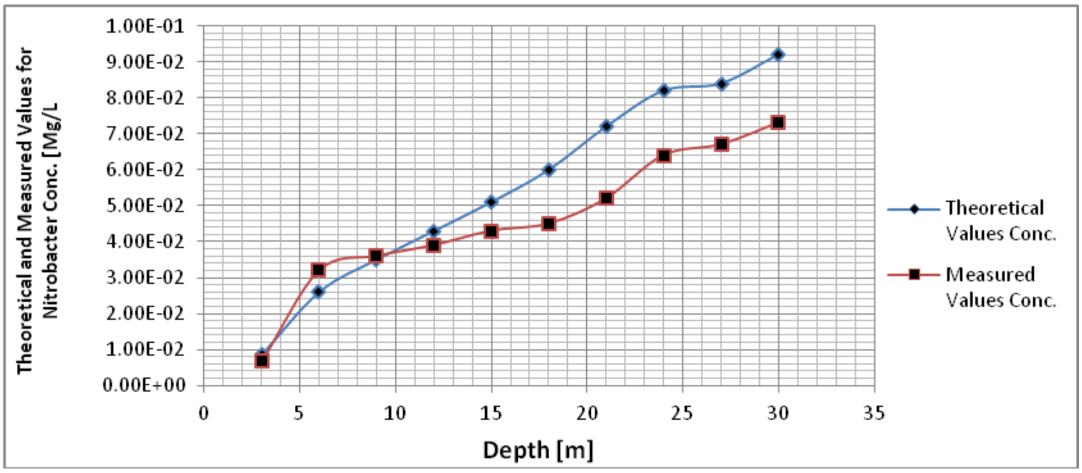

Figure: 7 Theoretical and Measured values of Nitrobacter Concentration at Different Depth

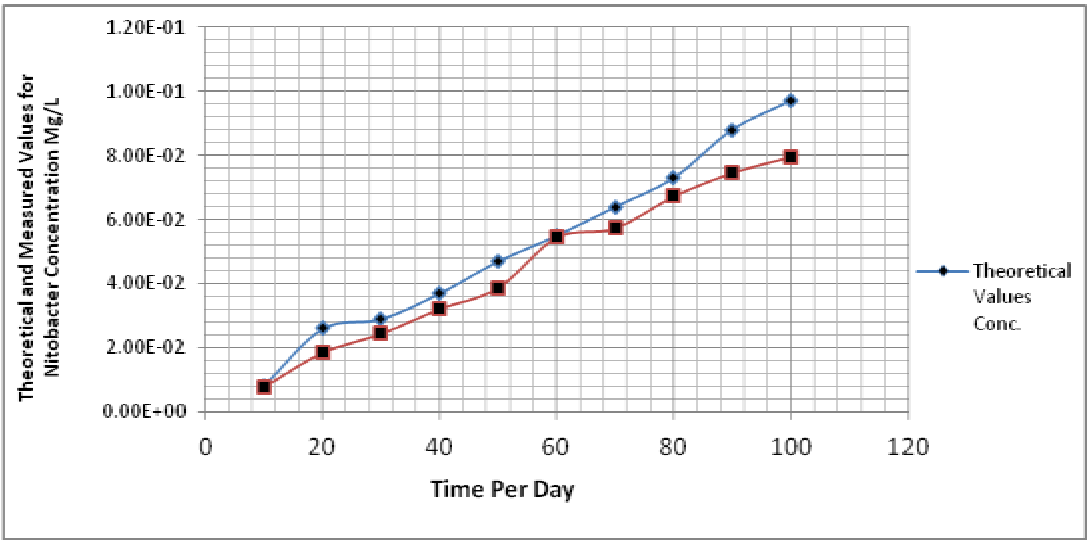

Figure: 8 Theoretical and Measured values of Nitrobacter Concentration at Different Time

The graphical representation of Nitrobacter concentration at different depth and time are shown in Figures 1 to 8.

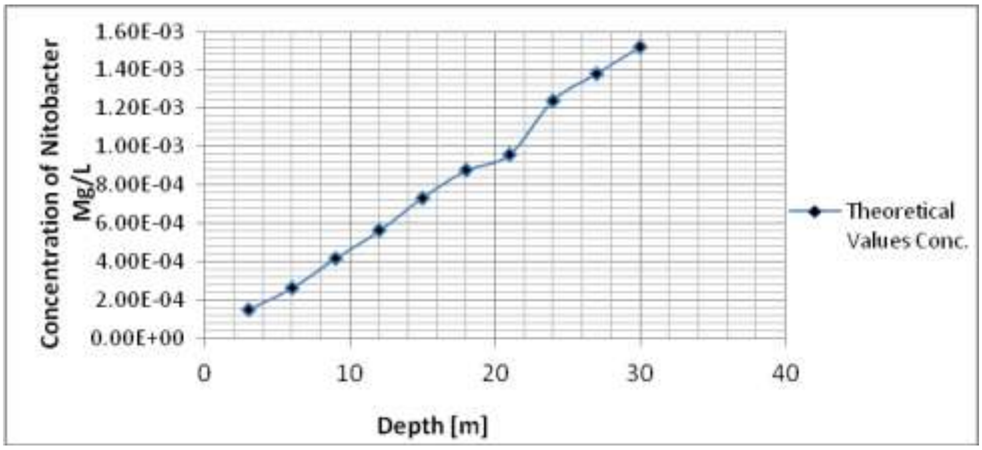

Figure 1: Theoretical vales of Nitrobacter at Different Depth

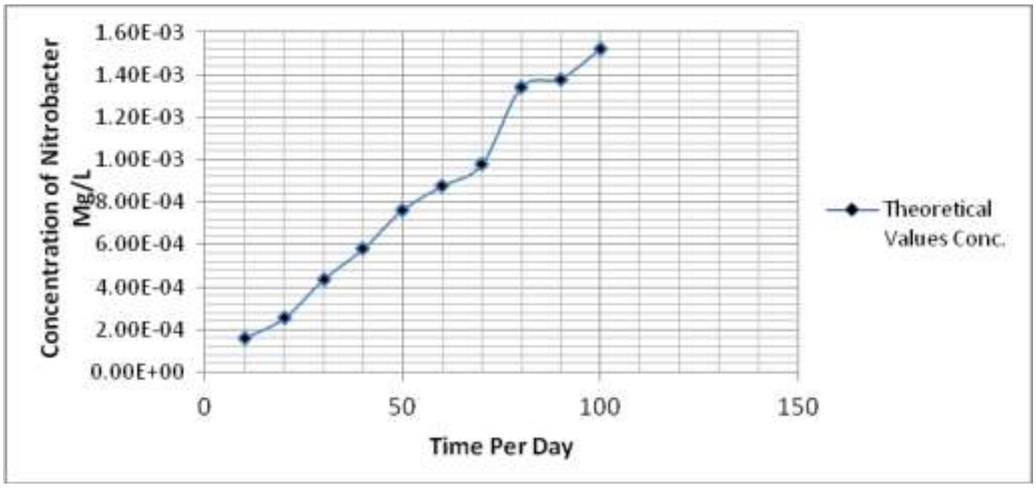

Figure 2: Theoretical vales of Nitrobacter at Different Time

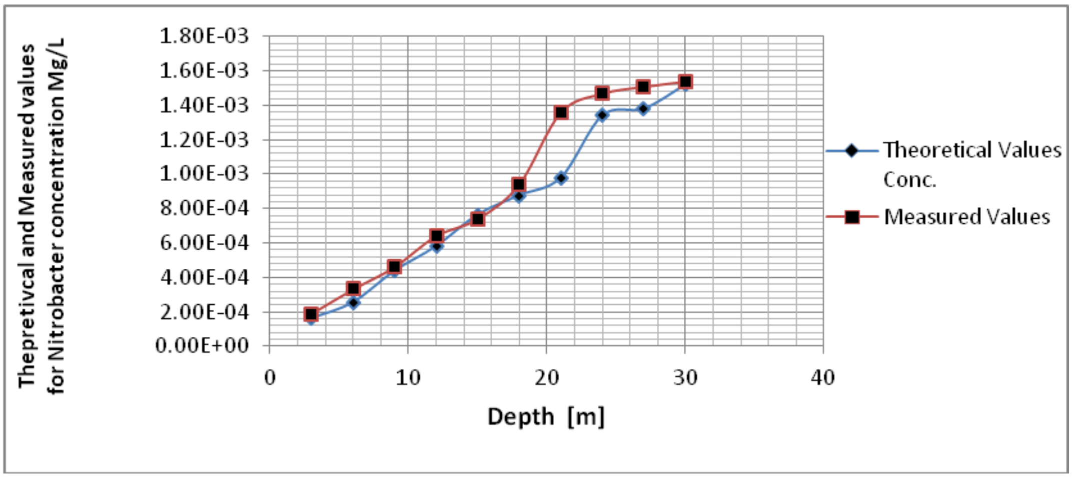

Figure 3: Theoretical and Measured values of Nitrobacter Concentration at Different Depth

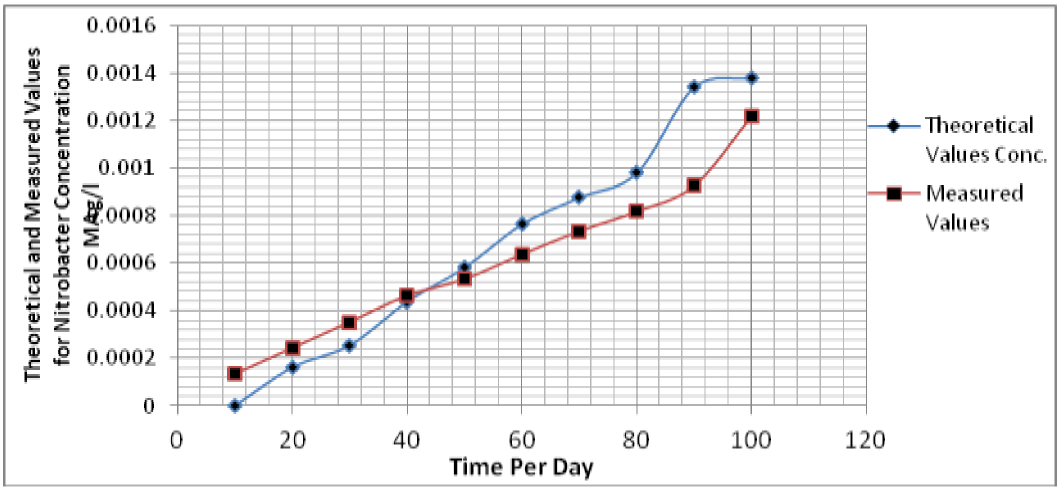

Figure 4: Theoretical and Measured values of Nitrobacter Concentration at Different Time

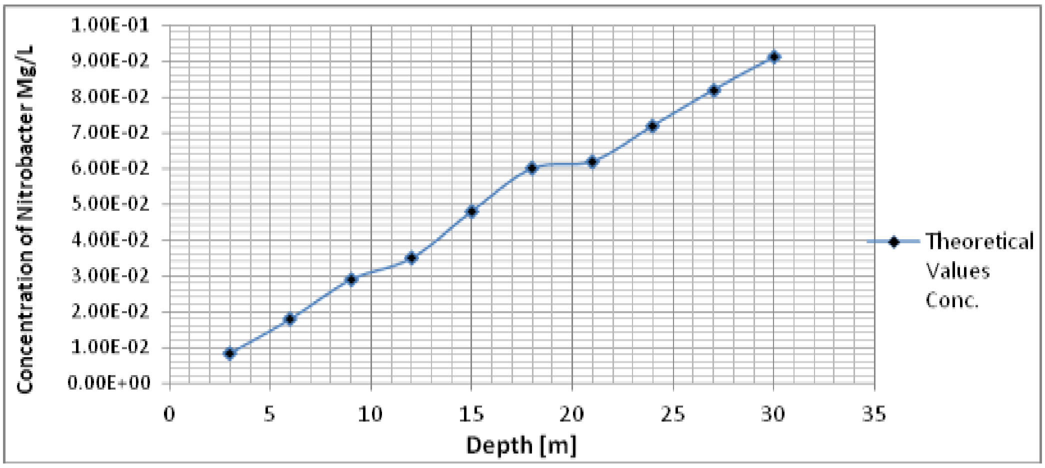

Figure 5: Theoretical vales of Nitrobacter at Different Depth

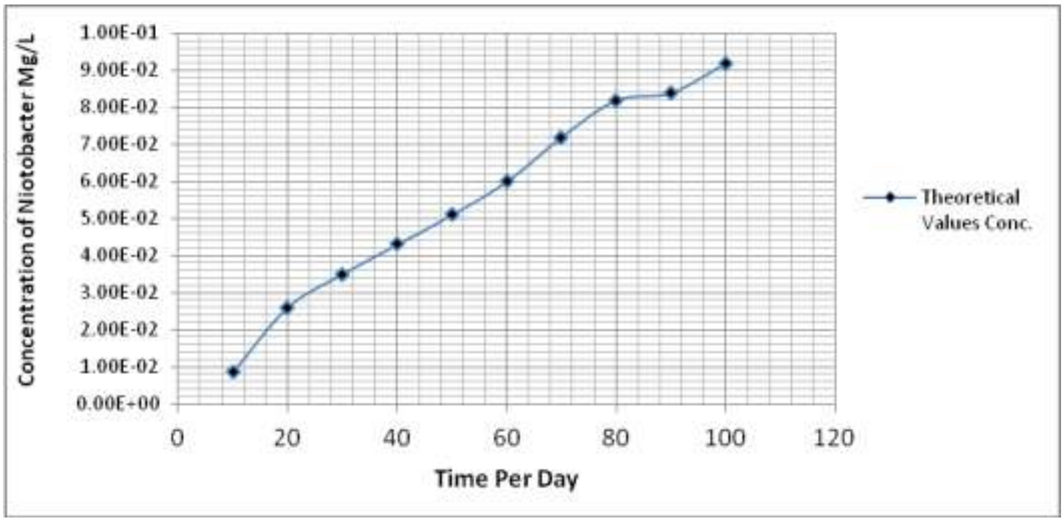

Figure 6: Theoretical vales of Nitrobacter at Different Time

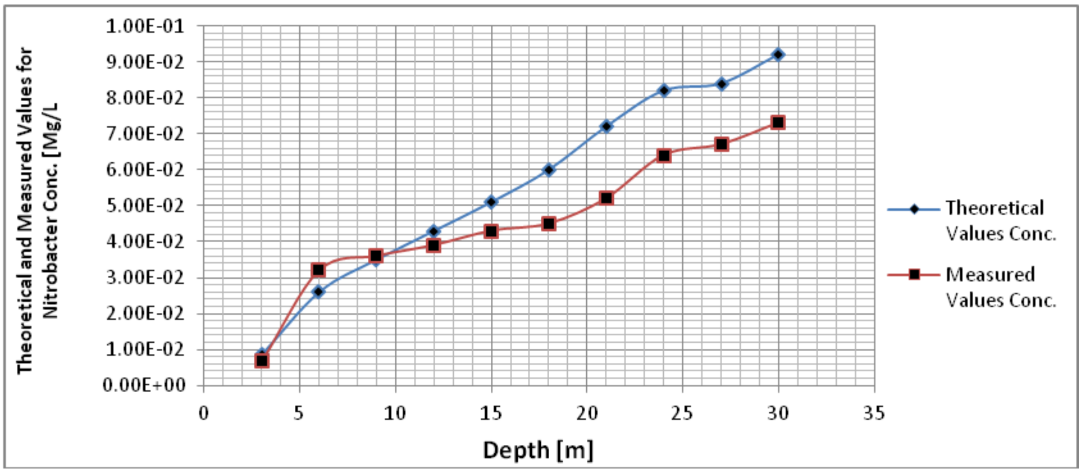

Figure: 7 Theoretical and Measured values of Nitrobacter Concentration at Different Depth

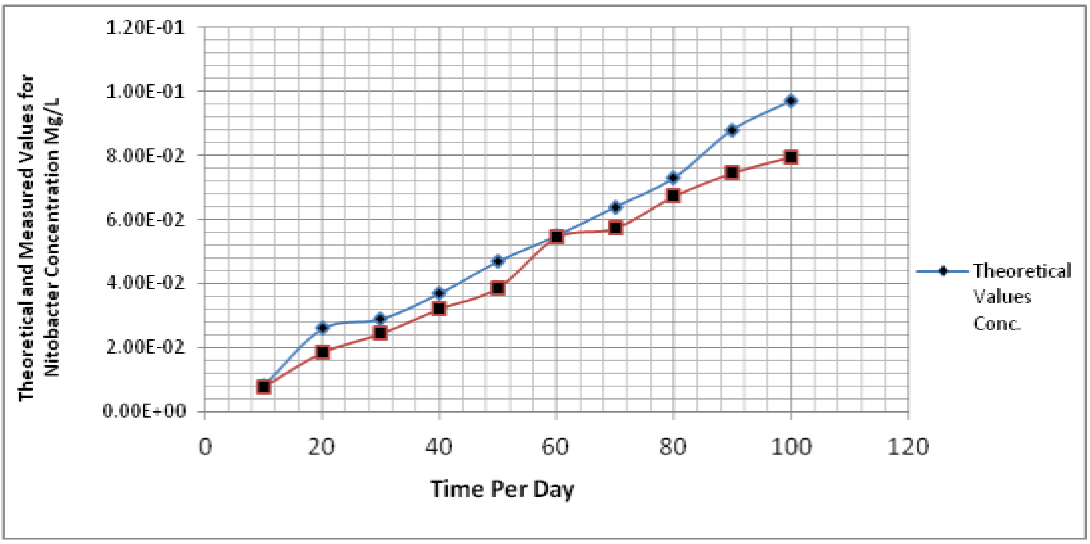

Figure: 8 Theoretical and Measured values of Nitrobacter Concentration at Different Time

IV. DISCUSSIONS

The results from the graphical representation expressed the migration rate and behavior of the Nitrobacter in the study area (saline environment). The concentrations are in exponential phase and the condition of the Nitrobacter deposition including its rate of concentration has shown concern to human and it environments. The deposition of Nitrobacter in the study location was observed from the developed model pressured by predominant deposition formation characteristics. This parameter is known as permeability. Formation parameter influences the deposition of Nitrobacter migration and concentration under the influences of permeability was discovered to be the predominantly higher in the study location. Fig. 1 expressed the migration rate under exponential phase with vacillation to the optimum level recorded at 30m. Fig. 2 in the same vein expressed the behaviour of transport base on the pressure of permeability to determine the time of transport from 10 to 100 days thus, fluctuation was observed from the lowest to the optimum level. Fig. 3 expressed the comparison between the theoretical and measured values with respect to depth. Vacillation was also observed from the lowest to the optimum level recorded at 30m. Fig. 4 compared the theoretical and measured values with respect to time. Fluctuations were also observed but both parameters expressed faviourable fits. Fig. 5 expressed slight oscillation from the lowest to the optimum rate recorded at 30m while Fig. 6 developed similar expression but with slight fluctuation between 99 and 100 days. Fig. 7 explained the validation of the model by the comparison between the theoretical and measured values. Both parameter expressed fluctuation from the lowest to the highest at 30m and best fit were observed. In Fig. 8, the theoretical values expressed sight vacillation between 10 to 30 days and this developed a rapid increase to the optimum at 100 days, while the measured values developed vacillation between 60 and 80 days and then migrate to the optimum at 100 days.

V. CONCLUSION

Nitrobacter were found in the study area and their depositions were evaluated to monitor it migration process on such predominant saline environments. The application was through mathematical modeling techniques and the system of this transport at the study area was developed by generating derived governing equation. The derived equation generated model that was simulated to determined the behaviour of Nitrobacter in saline coastal location. The transport of Nitrobacter has been express from the developed model through the simulation values and the results were compared with other measured values. Both parameters developed a favuorable fits validating the developed model. The study in this location was able to express insignificant effect of saline deposition on the migration of the Nitrobacter at coastal environments. However, the study was able to assess the rate of transport and other influences that pressured the behaviour of Nitrobacter in the study location. The result showed that the behaviour of Nitrobacter depends on the deposition of the structural setting of the formation and permeability influences its rate of transport at this study area. These conditions were observed to pressure the concentration process of Nitrobacter in coastal environments. Thus, the study has developed a base line study that will be applied in monitoring and evaluation of Nitrobacter deposition including its behaviour in costal environments. There is no doubt that the processes were imperative to confirm it rates of concentration because of the health implication this pollutant has cause to the human settlers in the study area. Experts will ensure that these conceptual techniques will be applied proactively to eradicate ground water pollution in the study environment.

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