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Modelling and Simulation to Predict Partial Mobile Velocity Effect on Clostridium Transport in Heterogeneous Lateritic and Silty Formation in Ahoada West, Rivers State of Nigeria

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Abstract: This paper is to predict the behaviour of clostridium transport in heterogeneous lithostratification depositions. Heterogeneity of the concentration were also monitored, fluctuation were observed base on the pressure from several phase considered in the system to monitor the transport process of these type of microbial specie. The depositions of this contaminant were observed to experiences lots of vacillations base on the deposition of substrate in the strata through their migration process. Partial mobile velocity was also observed in the system in most structured deposition of the formation thus affect the transport by developing accumulation of the contaminant in some deposited strata. These were observed to reflect on degree of porosity pressure including stratification variation experiences in the study area. simulation were carried out for validation of the derived model for the study, theoretical values generated were compared with experimental data, and both parameters developed best fits expressing validation of the model. The study is imperative because it has reflected in the behaviour of the clostridium under the influences of micronutrient, this affect its rate of concentration on ground water quality, experts in the field will definitely find these model useful in monitoring and investigation of ground water quality in deltaic environment.

Keywords: Modelling and Simulation, Velocity, Clostridium, Silty and Lateritic

1. Introduction

Uniformity of stratum is based on geologic history and geomorphology; including the geochemistry that influences the constituent of the formation, [1, 2, 4, 5, 6, 7, and 20]. The topography is under persuading of tides which a consequence is flooding especially during rainy season [19, 20, 28, and 29]. Climatically, the city is situated within the sub-equatorial region with the tropical monsoon weather characterized by high temperatures, low. [1]). The soil in the area is mainly silty-clay with interaction of sand and gravel while the vegetation is an amalgamation of mangrove swamp forest and rainforest [27 and 28]. Rivers state falls within the Niger Delta Basin of Southern Nigeria which is defined geologically by three sub-surface sedimentary facies: Akata, Agbada and Benin formations [25]. The Benin Formation (Oligocene to Recent) is the Aquiferous formation in the study area with an average thickness of about 2100m at the centre of the basin and consists of coarse to medium grained sandstone, gravels and clay with an average thickness of about 2100m at the centre of the basin and consists of coarse to medium grained sandstone, gravels and clay [2 and 13]. The Agbada Formation consists of alternating deltaic (fluvial coastal, fluviomarine) and shale, while Akata Formation is the basal sedimentary unit of the entire Niger Delta, consisting of low density, high pressure shallow marine to deep water shale [9, 18, 19, and 26]. The geochemical characteristics of the groundwater in turn influence the quality of the groundwater resources. Earlier works by [2, 4, 5, 6, 7, 9 10 12, 12, 13, 14, 15, 16, 17 and, 26], have confirmed the influence of local geology on the aquifer characteristics and quality of groundwater resources of any area. Human activities may also influence the quality of groundwater in the region [5]. Groundwater has been described as the main source of potable water supply for domestic, industrial and agricultural uses in the southern part of Nigeria especially the Niger Delta.[16, 17, 18, 19, 2021, 22, 23, 24]. Pollution of groundwater has gradually been on the increase especially in our cities with lots of industrial activities, population growth, poor sanitation, land use for commercial agriculture and other factors responsible for environmental degradation [12, 14, 15, and 23]. Some of these wastes could contain toxic components such as the polynuclear aromatic hydrocarbons (PAHs), which have been reported to be the real contaminants of oil and most abundant of the main hydrocarbons found in the crude oil mixture [10 15, 16, and 29]. Once introduced in the environment, PAHs could be stable for as short as 48 hours (e.g. naphthalene) or as long as 400 days (e.g. fluoranthene) in soils [18, 19, 21, 22, 23, 24, 25, 26 27 28 29]. They thus, resist degradation and, remain persistent in sediments and when in organisms, could accumulate in adipose tissues and further transferred up the trophic chain or web [21, 22, 24, 28, and 29].

2. Governing Equation

$$K\frac{d^2c}{dx^2} - \varphi\frac{dc}{dx} + V_t\frac{dc}{dx} = 0 \quad (1)$$

$$K\frac{d^2c}{dx^2} - (\varphi - V_t)\frac{dc}{dx} = 0 \quad (2)$$

$$\text{Let } C = \sum_{n=0}^{\infty} a_n x^n$$

$$C^1 = \sum_{n=1}^{\infty} n a_n x^{n-1}$$

$$C^{11} = \sum_{n=2}^{\infty} n(n-1) a_n x^{n-2}$$

$$K\sum_{n=2}^{\infty} n(n-1) a_n x^{n-2} - (\varphi - V_t)\sum_{n=1}^{\infty} n a_n x^{n-1} = 0 \quad (3)$$

Replace n in the 1st term by $n+2$ and in the 2nd term by $n+1$, this can be express as;

$$K\sum_{n=2}^{\infty} n(n+2)(n+1) a_{n+2} x^n - (\varphi - V_t)\sum_{n=0}^{\infty} (n+1) a_{n+1} x^n = 0 \quad (4)$$

i.e.

$$K(n+2)(n+1)a_{n+2} = (\varphi - V_t)(n+1)a_{n+1} \quad (5)$$

$$a_{n+2} = \frac{(\varphi - V_t)(n+1)a_{n+1}}{K(n+2)(n+1)} \quad (6)$$

$$a_{n+2} = \frac{(\varphi - V_t)a_{n+1}}{K(n+2)} \quad (7)$$

for

$$n = 0,\ a_2 = \frac{(\varphi - V_t)a_1}{2K} \quad (8)$$

for

$$n = 1,\ a_3 = \frac{(\varphi - V_t)a_2}{3K} = \frac{(\varphi - V_t)^2 a_1}{2K \bullet 3K} \quad (9)$$

for

$$n = 2;\ a_4 = \frac{(\varphi - V_t)a_3}{4K} = \frac{(\varphi - V_t)}{4K} \bullet \frac{(\varphi - V_t)a_1}{3K \bullet 2K} = \frac{(\varphi - V_t)^3 a_1}{4K \bullet 3K \bullet 2K} \quad (10)$$

for

$$n = 3;\ a_5 = \frac{(\varphi - V_t)}{5K} = \frac{(\varphi - V_t)^4 a_1}{5K \bullet 4K \bullet 3K \bullet 2K} \quad (11)$$

for

$$n;\ a_n - \frac{(\varphi - V_t)^{n-1} a_1}{K^{n-1} n!} \quad (12)$$

$$C(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + a_5 x^5 + ...a_n x_n \quad (13)$$

$$= a_0 + a_1 x + \frac{(\varphi - V_t)a_1 x^2}{2!K} + \frac{(\varphi - V_t)a_1 x^3}{3!K^2} + \frac{(\varphi - V_t)x^4}{4!K^3} + \frac{(\varphi - V_t)^5}{5!K^4} \quad (14)$$

$$C(x) = a_0 + a_1\left[\frac{(\varphi - V_t)x}{2!K} + \frac{(\varphi - V_t)^2 x^3}{3!K^2} + \frac{(\varphi - V_t)^3}{4!K^3} + \frac{(\varphi - V_t)^4}{5!K^4}\right] \tag{15}$$

$$C(x) = a_0 + a_1 \ell^{\frac{(\varphi - V_t)}{K}x} \tag{16}$$

Subject equation (16) to the following boundary condition

$$C(o) = 0 \; and \, C(o) = H$$

$$C(x) = a_0 + a_1 \ell^{\frac{(\varphi - V_t)}{K}x}$$

$$C(o) = a_0 + a_1 = 0$$

i.e.

$$a_0 + a_1 = 0 \tag{17}$$

$$C^1(x) = \frac{(\varphi - V_t)}{2!K} a_1 \ell^{\frac{(\varphi - V_t)}{K}x}$$

$$C^1(o) = \frac{(\varphi - V_t)}{2!K} a_1 = H$$

$$a_1 = \frac{HK}{\varphi - V_t} \tag{18}$$

Substitute (18) into equation (17)

$$a_1 = a_0$$

$$\Rightarrow a_0 = \frac{-HK}{\varphi - V_t} \tag{19}$$

Hence the particular solution of equation (16) is of the form:

$$C(x) = -\frac{HK}{\varphi - V_t} + \frac{HK}{\varphi - V_t} \ell^{\frac{(\varphi - V_t)}{K}x}$$

$$\Rightarrow C(x) = \frac{HK}{\varphi - V_t}\left[\ell^{\frac{(\varphi - V_t)}{K}x} - 1\right] \tag{20}$$

If $x = V \bullet t$

$$\therefore \; C(x) = \frac{HK}{\varphi - V_t}\left[\ell^{\frac{(\varphi - V_t)}{K}V \bullet t} - 1\right] \tag{21}$$

If $T = \frac{d}{V}$

$$C(x) = \frac{HK}{\varphi - V_t}\left[\ell^{\frac{(\varphi - V_t)}{K}\frac{d}{V}} - 1\right] \tag{22}$$

3. Materials and Method

Standard laboratory experiment where performed to monitor the concentration of clostridium at different formation, the soil deposition of the strata were collected in sequences base on the structural deposition at different locations, this samples collected at different location generated variation at different depth producing different migration of clostridium concentration through pressure flow at the lower end of the column, the experimental result are applied to be compared with theoretical values or model validation.

4. Result and Discussion

Results and discussion are presented in tables including graphical representation of clostridium concentration

Figure one to two experiences exponential concentration in the migration process of clostridium in the study location. The figures express linear phase under the influences from high degree of porosity deposited in those strata, such condition pressured the behaviour of the transport process on exponential phase thus determined the rate of concentration of the contaminant in the study area, exponential growth in the formation can be attributed to micronutrient depositions in lithostratification of the formation. such substance found influences the migration process, through their growth rate, it become an advantage to the microbial transport as this substrate increase it concentration, the figures expresses higher rate of concentration through predominant high degree of porosity in the formation, while figure three and four experiences exponential phase and suddenly developed fluctuation at fifty metres. Those region that experiences low concentration are based on the plasticity in lateritic deposition, these are soil that deposit higher plastic content in those region, the formation generated low porosity, this contaminant migration process experiences accumulation base on these factors. Figure five and six observed similar condition in exponential migration process developed between three and eighteen metres, sudden decrease were experiences from twenty one to the minimum rate deposited at thirty nine metres. Figure seven and eight observed slight similar condition were gradual migration was experiences to the optimum rate at fifteen metres, while sudden decline in concentration were experiences, it also express minimum rate of concentration at thirty metres. But although there is the tendency were this condition may be insignificant in transport due other factors, but this region precisely experiences some rate of fluctuation due to deposition variations in substrate in including impermeable depositions in the formation.

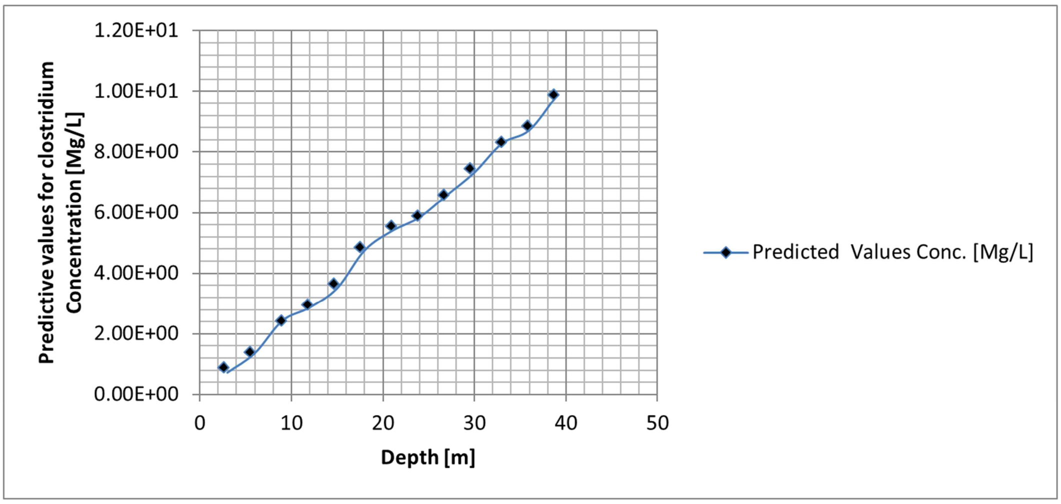

Figure 1. *Concentration of clostridium at Different Depth.*

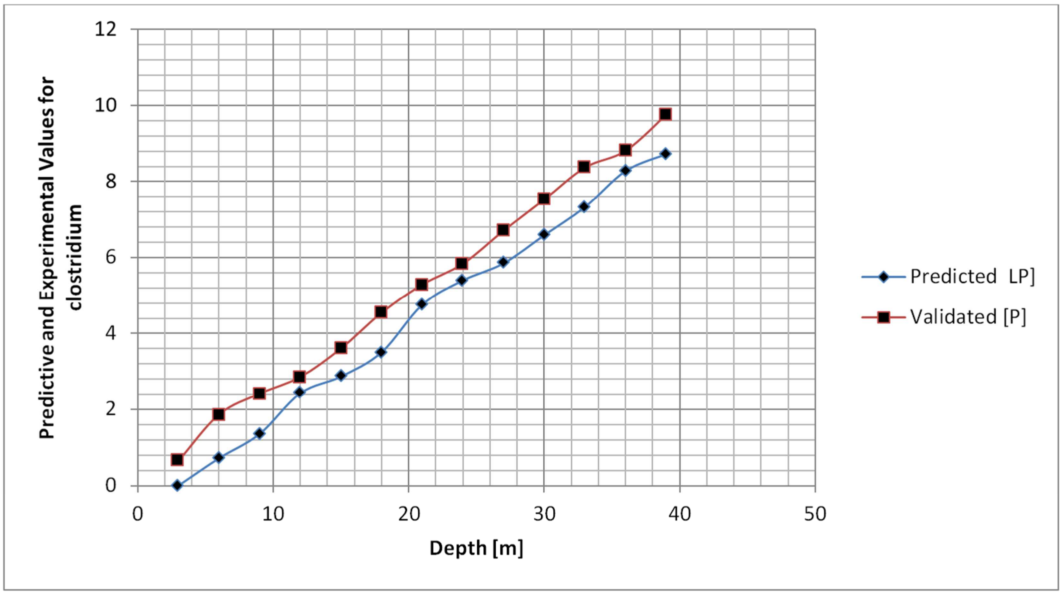

Figure 2. *Predicted and Validate Concentration of clostridium at Different Depth.*

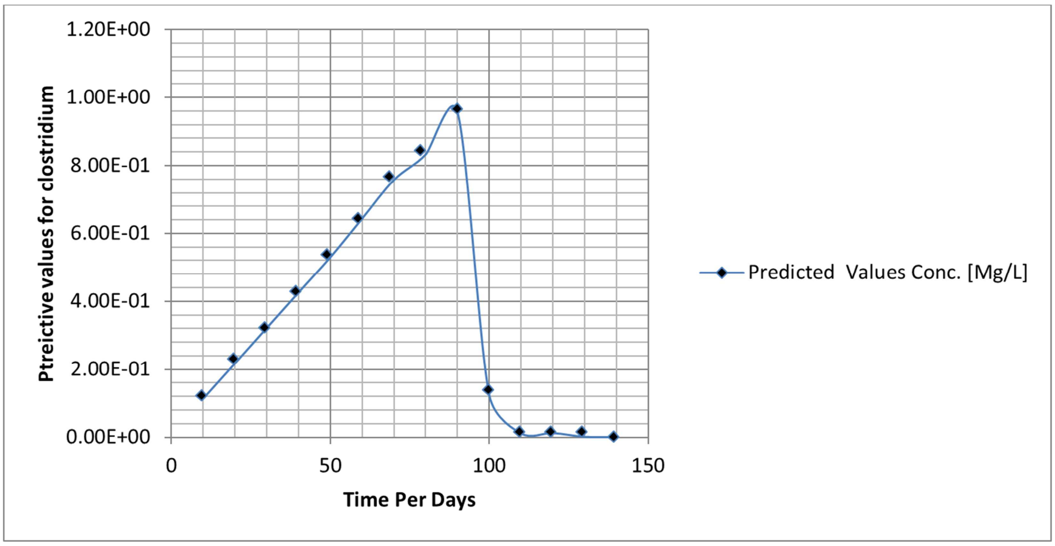

Figure 3. *Concentration of clostridium at Different Depth.*

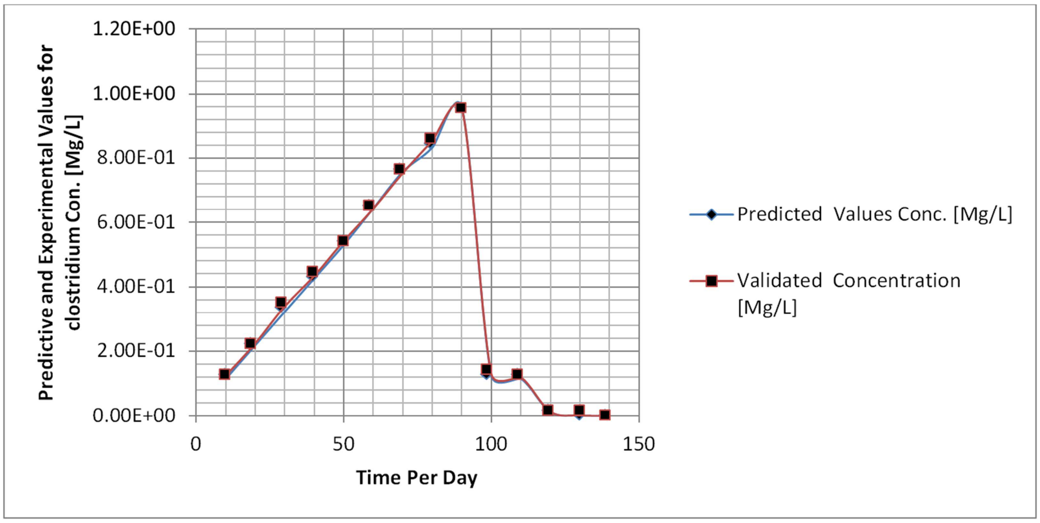

Figure 4. *Predicted and Validate Concentration of clostridium at Different Depth.*

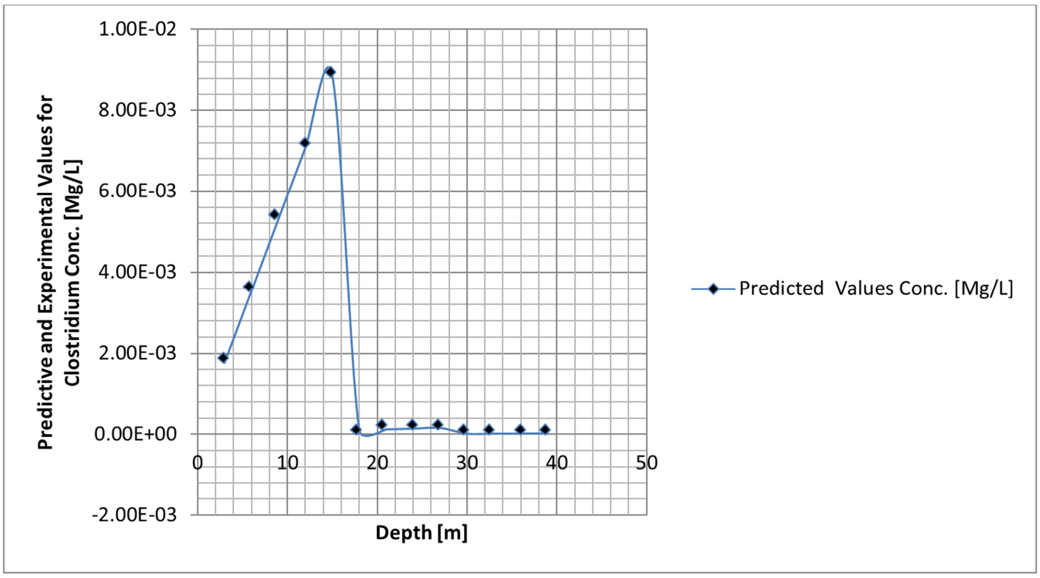

Figure 5. *Concentrationof clostridium at Different Depth.*

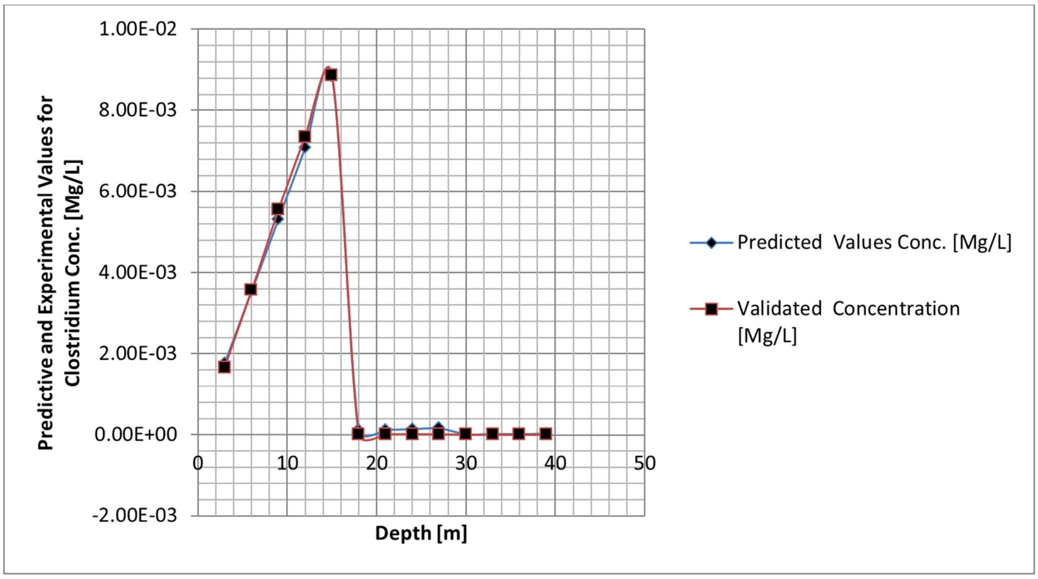

Figure 6. *Predicted and Validate Concentration of clostridium at Different Depth.*

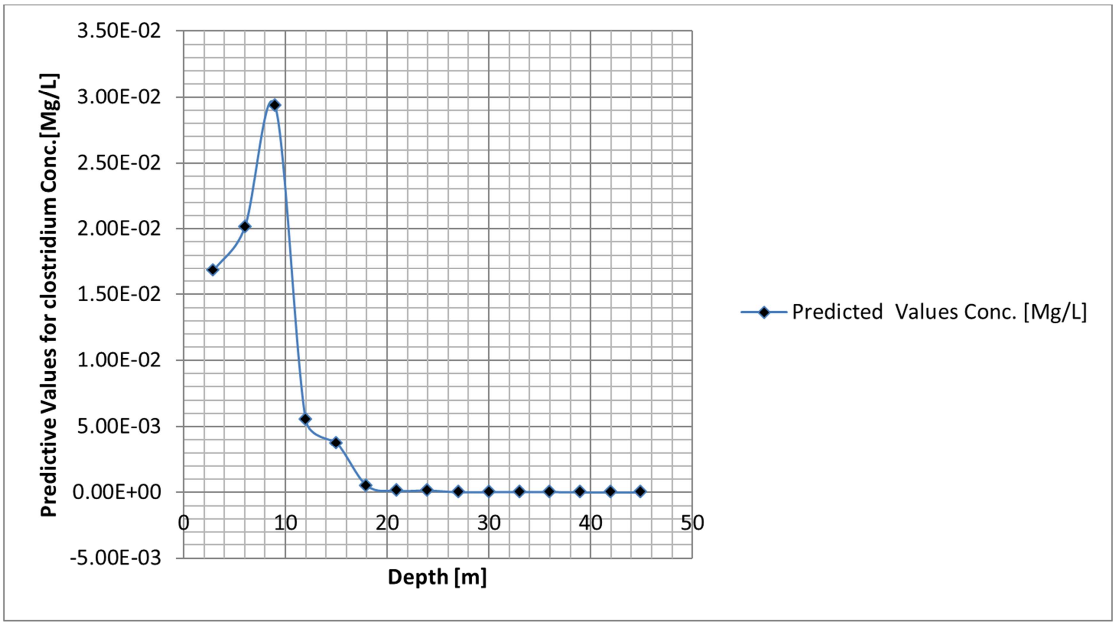

Figure 7. *Concentration of clostridium at Different Depth.*

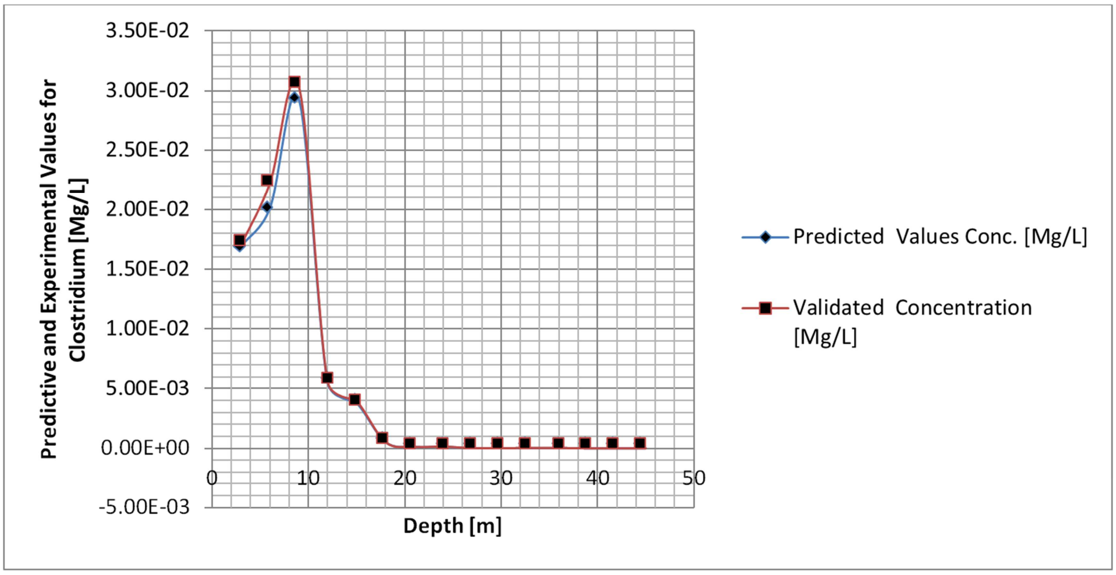

Figure 8. *Predicted and Validate Concentration of clostridium at Different Depth.*

Table 1. *Concentration of clostridium at Different Depth.*

Depth [M]	Predicted Values Conc. [Mg/L]
3	7.20E-01
6	1.36E+00
9	2.43E+00
12	2.87E+00
15	3.51E+00
18	4.76E+00
21	5.40E+00
24	5.85E+00
27	6.59E+00
30	7.33E+00
33	8.28E+00
36	8.72E+00
39	9.86E+00

Table 2. *Predicted and Validate Concentration of clostridium at Different Depth.*

Depth [M]	Predicted	Validated [P]
3	Predicted Values Conc. [Mg/L]	0.65
6	7.20E-01	1.87
9	1.36E+00	2.42
12	2.43E+00	2.86
15	2.87E+00	3.61
18	3.51E+00	4.55
21	4.76E+00	5.29
24	5.40E+00	5.84
27	5.85E+00	6.71
30	6.59E+00	7.53
33	7.33E+00	8.37
36	8.28E+00	8.81
39	8.72E+00	9.76
	9.86E+00	9.81

Table 3. *Concentration of clostridium at Different Depth.*

Time [T]	Predicted Values Conc. [Mg/L]
10	1.14E-01
20	2.18E-01
30	3.22E-01
40	4.26E-01
50	5.30E-01
60	6.44E-01
70	7.58E-01
80	8.33E-01
90	9.57E-01
100	1.24E-01
110	1.15E-01
120	1.24E-02
130	1.35E-03
140	1.46E-04

Table 4. *Predicted and Validate Concentration of clostridium at Different Depth.*

Time [T]	Predicted Values Conc. [Mg/L]	Validated Concentration [Mg/L]
10	1.14E-01	0.124
20	2.18E-01	0.224
30	3.22E-01	0.339
40	4.26E-01	0.434
50	5.30E-01	0.542
60	6.44E-01	0.643
70	7.58E-01	0.754
80	8.33E-01	0.854
90	9.57E-01	0.955
100	1.24E-01	0.129
110	1.15E-01	0.119
120	1.24E-02	0.013
130	1.35E-03	0.00138
140	1.46E-04	0.000149

Table 5. *Concentration of clostridium at Different Depth.*

Depth [M]	Predicted Values Conc. [Mg/L]
3	1.77E-03
6	3.54E-03
9	5.31E-03
12	7.08E-03
15	8.85E-03
18	1.06E-04
21	1.23E-04
24	1.41E-04
27	1.59E-04
30	1.77E-05
33	1.94E-05
36	2.12E-05
39	2.30E-05

Table 6. *Predicted and Validate Concentration of clostridium at Different Depth.*

Depth [M]	Predicted Values Conc. [Mg/L]	Validated Concentration [Mg/L]
3	1.77E-03	1.68E-03
6	3.54E-03	3.56E-03
9	5.31E-03	5.54E-03
12	7.08E-03	7.35E-03
15	8.85E-03	8.88E-03
18	1.06E-04	1.28E-05
21	1.23E-04	1.42E-05
24	1.41E-04	1.61E-05
27	1.59E-04	1.71E-05
30	1.77E-05	1.87E-06
33	1.94E-05	1.99E-06
36	2.12E-05	2.29E-06
39	2.30E-02	2.41E-06

Table 7. *Concentration of clostridium at Different Depth.*

Depth [M]	Predicted Values Conc. [Mg/L]
3	1.69E-02
6	2.01E-02
9	2.93E-02
12	5.50E-03
15	3.80E-03
18	5.18E-04
21	1.18E-04
24	1.41E-04
27	1.52E-05
30	1.95E-05
33	2.55E-05
36	2.97E-05
39	2.05E-06
42	1.19E-06
45	1.86E-06

Table 8. *Predicted and Validate Concentration of clostridium at Different Depth.*

Depth [M]	Predicted Values Conc. [Mg/L]	Validated Concentration [Mg/L]
3	1.69E-02	1.70E-02
6	2.01E-02	2.22E-02
9	2.93E-02	3.04E-02
12	5.50E-03	5.57E-03
15	3.80E-03	3.95E-03
18	5.18E-04	5.22E-04
21	1.18E-04	1.24E-04
24	1.41E-04	1.48E-04
27	1.52E-05	1.61E-05
30	1.95E-05	2.05E-05
33	2.55E-05	2.66E-05
36	2.97E-05	3.09E-05
39	2.05E-06	2.15E-06
42	1.19E-06	1.23E-06
45	1.86E-06	1.94E-06

Figure one to two experiences exponential concentration in the migration process of clostridium in the study location. The figures express linear phase under the influences from high degree of porosity deposited in those strata, such condition pressured the behaviour of the transport process on exponential phase thus determined the rate of concentration of the contaminant in the study area, exponential growth in the formation can be attributed to micronutrient depositions in lithostratification the formation. such substance found influences the migration process, through their growth rate, it become an advantage to the microbial transport as this substrate increase it concentration, the figures expresses higher rate of concentration through predominant high degree of porosity in the formation, while figure three and four experiences exponential phase and suddenly developed fluctuation at fifty metres. Those region that experiences low concentration are based on the plasticity in lateritic deposition, these are soil that deposit higher plastic content in those region, the formation generated low porosity, this contaminant migration process experiences accumulation base on these factors. Figure five and six observed similar condition in exponential migration process developed between three and eighteen metres, sudden decrease were experiences from twenty one to the minimum rate deposited at thirty nine metres. Figure seven and eight observed slight similar condition were gradual migration was experiences to the optimum rate at fifteen metres, while sudden decline in concentration were experiences, it also express minimum rate of concentration at thirty metres. But although there is the tendency were this condition may be insignificant in transport due other factors, but this region precisely experiences some rate of fluctuation due to deposition variations in substrate in including impermeable depositions in the formation.

5. Conclusion

The investigation of clostridium in lateritic and silty formation has been evaluated through the transport process, the study were to monitor the rate of concentration base on the heterogeneity stratification observed in the study location. The developed model express it theoretical values base on the system developed to generated the derived model, simulation were carried out to determine the model verification, the figures from the theoretical values generated express best fits compared with experimental data, including fluctuation base on the deposition of substrate, the expression on the rates of concentration were observed to be attributed to lots of fluctuation in substrate deposition thus developed in some minerals in the formation, such heterogeneity observed in the transport system should be monitored for water quality in the study area.

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