Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2018, 5(3):67-77**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Modelling and Simulation to Monitor Permeability Influences on Clostridium Transport in Homogeneous Coarse Formation Mbiama, Rivers State of Nigeria

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Abstract In this work, several phases were considered in the derived model to monitor the migration process of these types of microbial specie. The deposition of these contaminants was observed to experience lots of vacillations on the migration process. This observed condition in the formation was noted to reflect the degree of porosity including stratification variation experienced in the study area. Such pressure is shown to influence the rate of clostridium transport in the study location. Simulation was 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 thereby validating the developed model. The results range from 1.30E- 8.39 at distances ranging from 3-45m, 1.04E-1.46E+00 at times ranging from 10 - 110 days, 1.77E-03-2.30E-02, 1.69E-05-1.86E-004 at distances ranging from 3-39m and 3-45m. The study is imperative because it has shown the behaviour of the microbes in its migration process. Thus its rate of concentration affects ground water quality. Experts in the field will definitely find this model useful in monitoring and evaluation of ground water quality in deltaic formations.

Keywords modelling and simulation, permeability, clostridium and coarse formation

1. Introduction

Uniformity of stratum is based on geologic history and geomorphology, including the geochemistry that influences the constituent of the formation; the characteristics determine the rate of microbial migration to ground water aquifers. Rivers State, "treasure base of the nation" is situated about 60 km from the open sea, lies between longitude 6o55'E to 7o10'E of the Greenwich meridian and latitude 4o38'N to 4o54'N of the Equator, covering a total land mass of about 804 km^2 [1]. In terms of drainage, the area is situated on the top of Bonny River and is entirely lowland with an average elevation of about 15m above sea level [2]. The topography is under persuading of tides which a consequence is flooding especially during rainy season [3-5]. Climatically, the city is situated within the sub-equatorial region with the tropical monsoon weather characterized by high temperatures, low pressure and high relative dampness all the year round. The mean annual temperature, rainfall and relative dampness are 30^oC, 2,300 mm and 90% respectively. 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 [5-6]. 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 [7-8]. 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 [9]. 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. The quantity and quality of ground water resources of any region are restricted by the climate and geology of the area. The climate through rainfall and surface water resources ensure steady supply or recharge to groundwater resources of an area in a complex hydrological cycle. The geology of the region determines the aquiferous zones where exploitable groundwater may occur and influences the geochemical characteristics of the groundwater, amongst other factors such as human activities [10]. The geochemical characteristics of the groundwater in turn influence the quality of the groundwater resources. Earlier works by Demenico, and Schwartz [11], Ahiarakwem and Ejimadu [12], Downey [13], Aniya and, Schoenekeck K [14], Idowu et al. [15] and Awalla and Ezeigbo [16] 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 [17]. 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, due to long retention time and natural filtration capacity of aquifers [17-19]. Water that is safe for drinking, pleasant in taste, and suitable for domestic purposes is designated as potable water and must not contain any chemical or biological impurity [20]. 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. The concentration of contaminants in the groundwater also depends on the level and type of elements introduced to it naturally or by human activities and distributed through the geological stratification of the area. It has been reported that petroleum refining contributes solid, liquid, and gaseous wastes in the environment [21-22]. 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 [23]. 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 [24]. 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 [25-26].

2. Governing Equation

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

$$K\frac{d^2c}{dx^2} - (\phi - V_t)\frac{dc}{dx} = 0 \quad \text{…………………..} \quad (2)$$

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

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

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

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

Replace *n* in the 1st term by *n+2* and in the 2nd term by *n+1*, so that we have;

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

i.e. $K(n+2)(n+1)a_{n+2} = (\phi - V_t)(n+1)a_{n+1}$ ………………….. (5)

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

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

$$\text{for } n = 0,\ a_2 = \frac{(\phi - V_t)a_1}{2K} \quad \ldots\ldots\ldots\ldots \quad (8)$$

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

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

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

$$\text{for } n;\ a_n - \frac{(\phi - V_t)^{n-1} a_1}{K^{n-1} n!} \quad \ldots\ldots\ldots\ldots \quad (12)$$

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

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

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

$$\boxed{C(x) = a_0 + a_1 \ell^{\frac{(\phi - V_t)}{K}x}} \quad \ldots\ldots\ldots\ldots \quad (16)$$

Applying the following boundary condition to equation(16),we have

$C(o) = 0$ *and* $C(o) = H$

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

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

$$\text{i.e. } a_0 + a_1 = 0 \quad \ldots\ldots\ldots\ldots \quad (17)$$

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

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

$$a_1 = \frac{HK}{\phi - V_t} \quad \ldots\ldots\ldots\ldots \quad (18)$$

Substituting (18) into equation (17), gives

$$a_1 = a_0$$

$$\Rightarrow a_0 = \frac{-HK}{\phi - V_t} \quad \ldots\ldots\ldots\ldots \quad (19)$$

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

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

$$\Rightarrow C(x) = \frac{HK}{\phi - V_t}\left[\ell^{\frac{(\phi - V_t)}{K}x} - 1\right] \qquad \ldots\ldots\ldots\ldots\ldots\ldots.. \qquad (20)$$

If $x = V \bullet t$

$$\therefore \quad C(x) = \frac{HK}{\phi - V_t}\left[\ell^{\frac{(\phi - V_t)}{K}V \bullet t} - 1\right] \qquad \ldots\ldots\ldots\ldots\ldots\ldots.. \qquad (21)$$

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

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

3. Materials and method

Standard laboratory experiment where performed to monitor the concentration of clostridium at different formation. The soil deposition of the strata was collected in sequences based on the structural deposition at different locations. The samples collected at different locations generated variations at different depth producing different migration of clostridium concentration through pressure flow at the lower end of the column. The experimental result are applied and compared with the theoretical values to validate the developed model.

4. Results and Discussion

Results are presented in tables including graphical representation of clostridium concentration

Table1: Concentration of clostridium at Different Depths

Depth [M]	Predicted Values Conc. [Mg/L]
3	7.30E-01
6	1.46E+00
9	2.23E+00
12	2.97E+00
15	3.71E+00
18	4.46E+00
21	5.20E+00
24	5.95E+00
27	6.69E+00
30	7.43E+00
33	8.18E+00
36	8.92E+00
39	9.66E+00

Table 2: Predicted and Validated Concentration of clostridium at Different Depths

Depth [M]	Predicted LP]	Validated [P]
3	7.30E-01	0.75
6	1.46E+00	1.47
9	2.23E+00	2.22
12	2.97E+00	2.96
15	3.71E+00	3.71

18	4.46E+00	4.45
21	5.20E+00	5.19
24	5.95E+00	5.94
27	6.69E+00	6.68
30	7.43E+00	7.43
33	8.18E+00	8.17
36	8.92E+00	8.91
39	9.66E+00	9.66

Table 3: Concentration of clostridium at Different Depths

Time [T]	Predicted Values Conc. [Mg/L]
10	1.04E-01
20	2.08E-01
30	3.12E-01
40	4.16E-01
50	5.20E-01
60	6.24E-01
70	7.28E-01
80	8.33E-01
90	9.37E-01
100	1.04E+00
110	1.15E+00
120	1.24E+00
130	1.35E+00
140	1.46E+00

Table 4: Predicted and Validated Concentration of clostridium at Different Depths

Time [T]	Predicted Values Conc. [Mg/L]	Validated Concentration [Mg/L]
10	1.04E-01	0.114
20	2.08E-01	0.214
30	3.12E-01	0.319
40	4.16E-01	0.424
50	5.20E-01	0.532
60	6.24E-01	0.633
70	7.28E-01	0.744
80	8.33E-01	0.844
90	9.37E-01	0.945
100	1.04E+00	1.09
110	1.15E+00	1.19
120	1.24E+00	1.3
130	1.35E+00	1.38
140	1.46E+00	1.49

Table 5: Concentration of clostridium at Different Depths

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-02
21	1.23E-02
24	1.41E-02
27	1.59E-02
30	1.77E-02
33	1.94E-02
36	2.12E-02
39	2.30E-02

Table 6: Predicted and Validated Concentration of clostridium at Different Depths

Depth [M]	Predicted Values Conc. [Mg/L]	Validated Concentration [Mg/L]
3	1.77E-03	1.88E-03
6	3.54E-03	3.66E-03
9	5.31E-03	5.44E-03
12	7.08E-03	7.15E-03
15	8.85E-03	8.98E-03
18	1.06E-02	1.18E-02
21	1.23E-02	1.32E-02
24	1.41E-02	1.51E-02
27	1.59E-02	1.66E-02
30	1.77E-02	1.84E-02
33	1.94E-02	1.99E-02
36	2.12E-02	2.24E-02
39	2.30E-02	2.40E-02

Table 7: Concentration of clostridium at Different Depths

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

Table 8: Predicted and Validated Concentration of clostridium at Different Depths

Depth [M]	Predicted Values Conc. [Mg/L]	Validated Concentration [Mg/L]
3	1.69E-05	1.70E-03
6	2.01E-05	2.22E-05
9	2.93E-04	3.04E-04
12	5.50E-05	5.57E-05
15	3.80E-02	3.95E-02

18	5.18E-02	5.22E-02
21	1.18E-03	1.24E-03
24	1.41E-03	1.48E-03
27	1.52E-02	1.61E-02
30	1.95E-02	2.05E-02
33	2.55E-02	2.66E-02
36	2.97E-02	3.09E-02
39	2.05E-04	2.15E-04
42	1.19E-04	1.23E-04
45	1.86E-04	1.94E-04

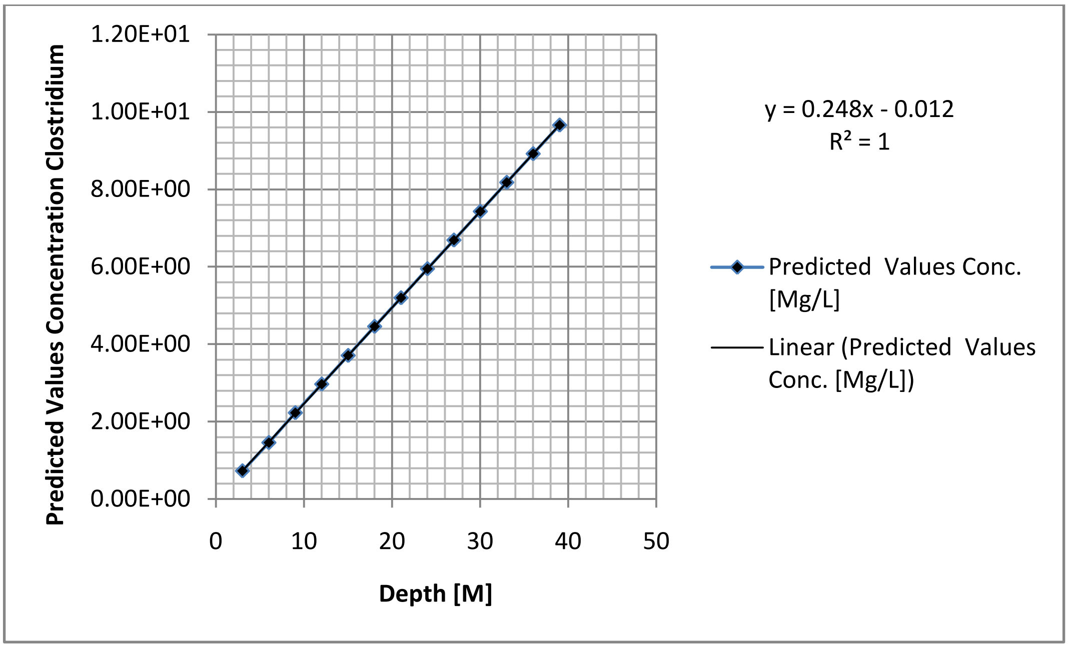

Figure 1: Concentration of clostridium at Different Depths

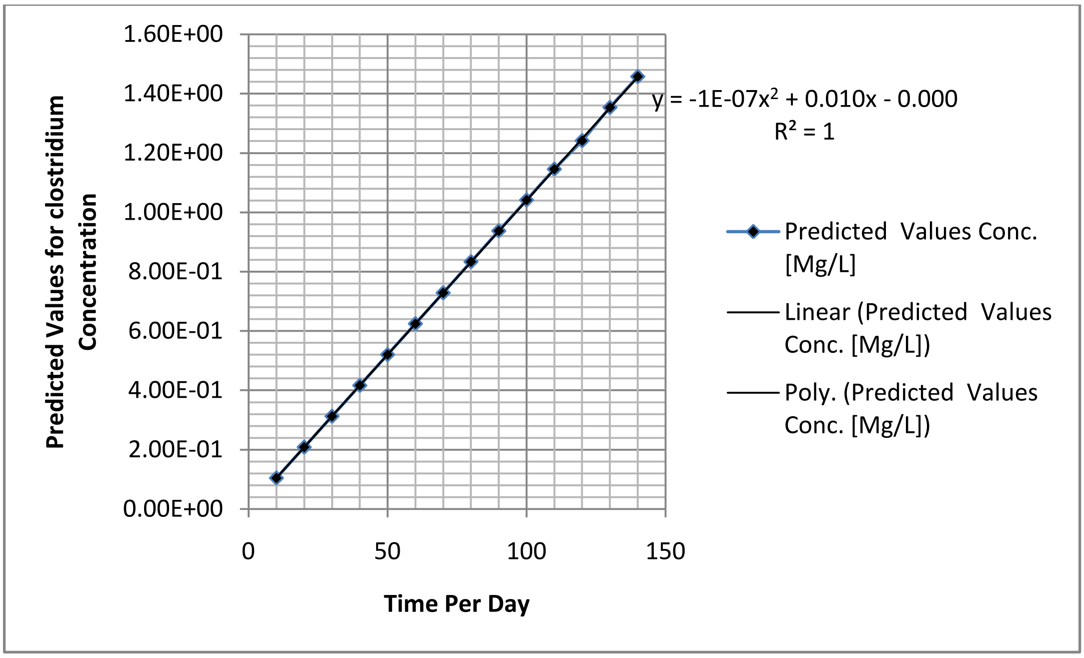

Figure 2: Predicted and Validated Concentration of clostridium at Different Depths

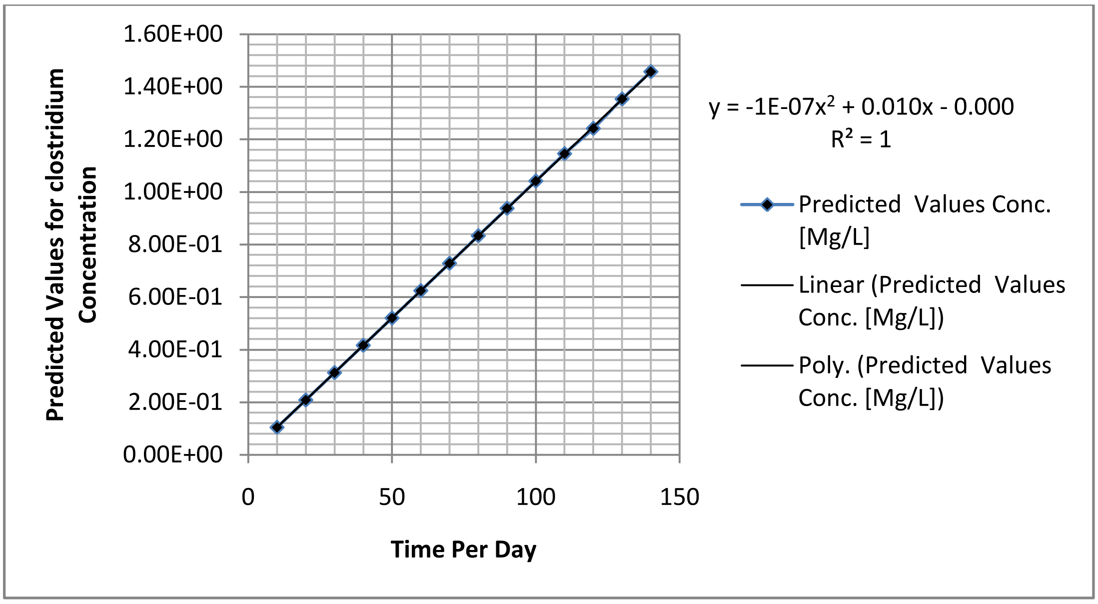

Figure 3: Concentration of clostridium at Different Depths

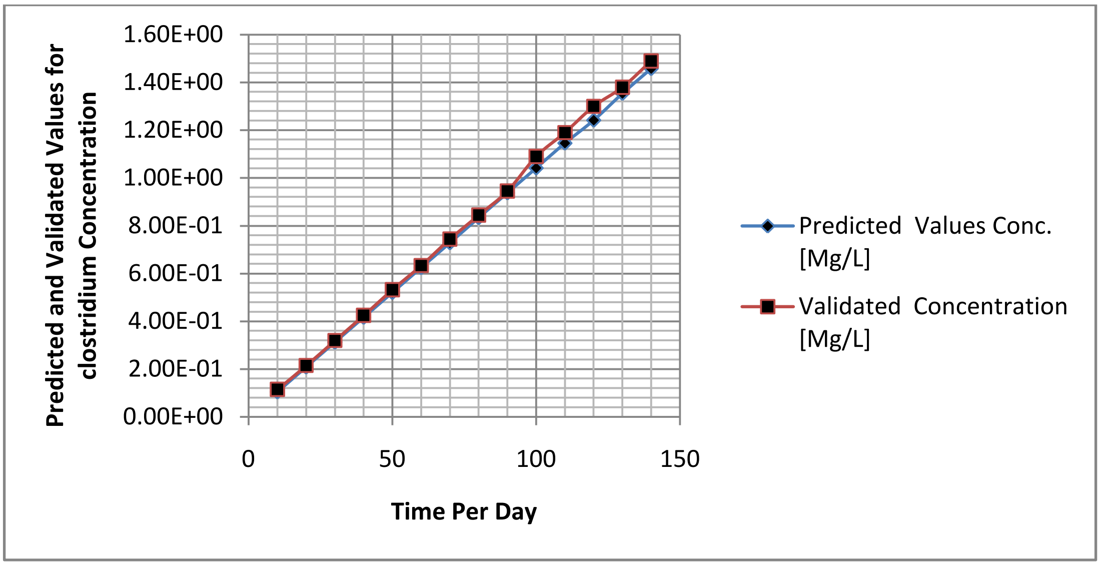

Figure 4: Predicted and Validated Concentration of clostridium at Different Depths

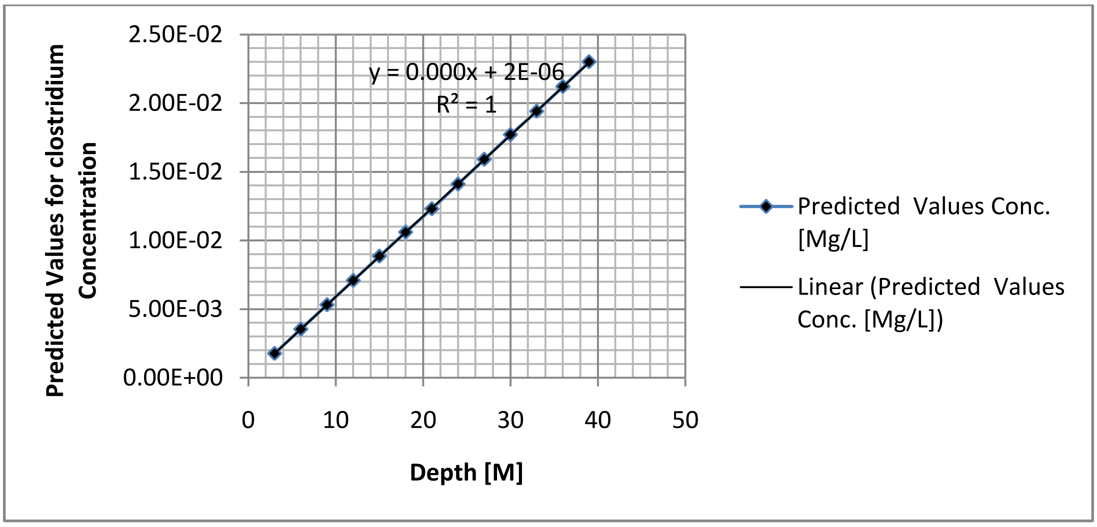

Figure 5: Concentration of clostridium at Different Depths

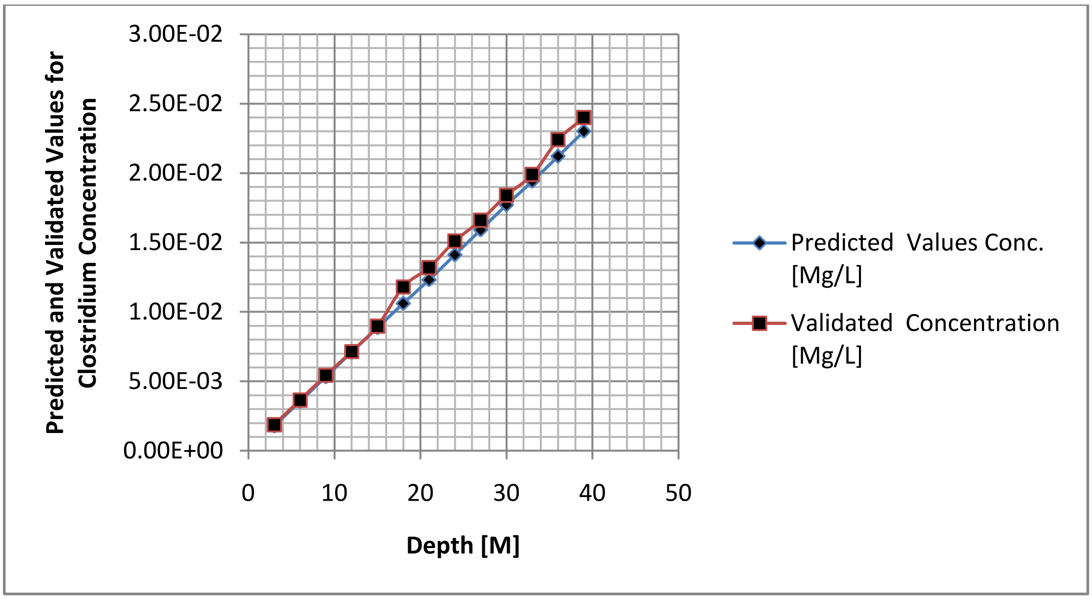

Figure: 6 Predicted and Validated Concentration of clostridium at Different Depths

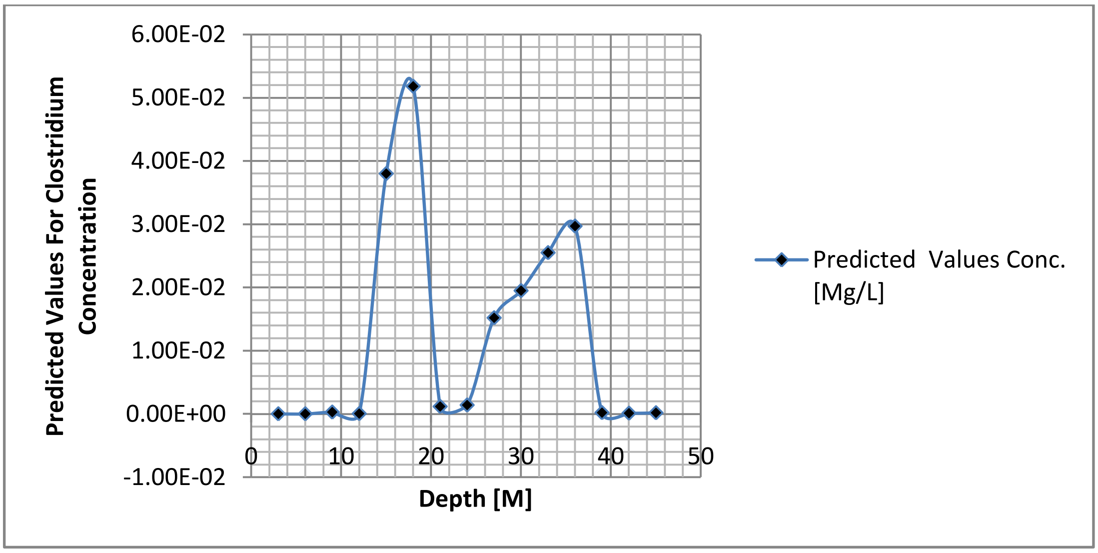

Figure: 7 concentration of clostridium at Different Depths

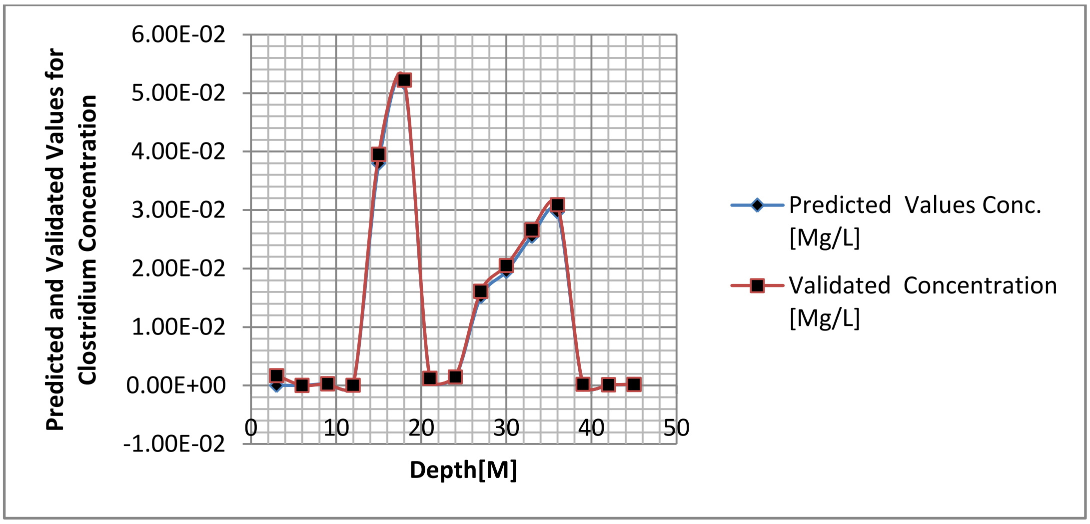

Figure: 8 Predicted and Validated Concentration of clostridium at Different Depths

Figure one to four experiences exponential concentration in the transport system of clostridium in the study area. The figures express fluctuations under the influences of porosity variation in strata, such condition pressured the behaviour of the transport process as exponential phase thus determined the rate of concentration of the contaminant in the study location, exponential growth in the formation can also be attributed to substrate deposition in some location of the formation were such substance are found, therefore on the migration process it become an advantage to the microbial transport as this substrate increase it concentration, the figures expresses higher rate of concentration through predominant higher degree of porosity in the formation, the region that low concentration were observed are base on the plasticity of the strata thus lateritic soil that has higher plastic limit that deposit clay content in those region in the formation generated low porosity, this contaminant migration process experiences low concentration base on these factors in the study location, although there is the tendency were this condition may be insignificant in transport due other factors, but these region precisely experiences low concentration due impermeable depositions in the formation, figure five and six express similar linear transport, but with its rates of concentration cannot be compared with other previous figures, this is due to changing in formation influences, the concentration experienced lower deposition compared to other discussed figures, the concentration recorded slight deposition in phreatic bed, while figure seven and eight experiences fluctuation in their migration process, the lowest at three metres depositing slight concentration while the optimum were recorded at fifteen to eighteen metres, twenty seven to thirty six metres respectively, the lowest were observed at thirty nine to forty five, the rate of deposition reflect the deposition of porosity in the study location, such phreatic beds must be thoroughly analyzed in construction and design of ground water system.

5. Conclusion

The deposition of clostridium concentration has been evaluated in 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 determined the model verification, the figures from the theoretical values generated express best fit compared with experimental data, the expression on the rates of concentration can be attributed to lots of several variation in strata and deposition of minerals in the formation, such heterogeneous observed in the transport system should be monitored in water quality in the study area. Experts will always find the monitoring and evaluation of ground water quality easier through the application of this developed model base on its verification.

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