Modelling Accumulation Ammonia Deposition Influenced Low Velocity in Silty Clay Formation, Industrial Layout of Port Harcourt

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Abstract: This paper evaluates the behaviour of Ammonia deposition in silty clay formation. The lithology of the formation through detailed investigation shows that the rate of hydraulic conductivity was observed to be very low in silty clay soil. the derived model were to monitor the behaviour of the soil in terms of Ammonia deposition in the study area, such conditions were monitored to have hinder the transport of Ammonia due to low deposition including permeation and void ratio of the soil, these were considered to have generated the accumulation of Ammonia in the study area. The developed model were monitored in industrial area were this substances were observed to predominantly deposited in these locations, such condition were essential to monitor and to predict the concentration rate in silty clay formation, the accumulation of this substance may migrate to porous medium and contaminate the Phreatic bed, more so, the deposited substances are known to be one of the substrate, this implies that it will definitely increase the deposition of any other microbial contaminant in the study area thus generate more contaminant in Phreatic bed. The developed model was simulated to generate theoretical values, these were compared with experimental values and both parameters express best fits validating the developed model for the study.

Keywords: Ammonia Accumulation, Low Velocity, Silty Clay Formation

1. Introduction

The studies of hydraulic conductivity are determined by the soil structural deposition. This influence of stratification is where variable that influence the soil matrix is expressed. The study of hydrocarbon transport spread on the soil causing environmental pollution is the focus of the study. The pollution sources are caused by some influences, which could be manmade activities or natural origin, the rate of oil exploration, without environmental risk assessment, and environmental statement are the major risk hazard, the stipulated environmental laws should be as a baseline in solving environmental related problems caused of manmade activities [21]. The transport and fate of groundwater contaminants is controlled by advective transport, dispersion, sorption to aquifer sediments, biological degradation, and other processes. Spatial variations in groundwater velocity are recognized to provide the dominant control on contaminant transport in most settings [1 - 4]. Groundwater velocity is proportional to hydraulic conductivity, which may vary by several orders of magnitude across small spatial ranges as a result of the geological processes that deposited and altered the sediments. Solutes follow the path of highest hydraulic conductivity, thus it is critical to identify these regions, as well as the low conductivity barriers that impede flow. Heterogeneity in hydraulic conductivity can be evaluated using a variety of methods including tracer tests, slug and pump tests, permeameter measurements on soil core samples, and borehole flow meter tests. [5-8]. Reported that hydraulic conductivity varied by 4 orders of magnitude over a 240 m long and 10 m deep region at Columbus Air Force Base in northeastern Mississippi using a borehole flow meter. Even in a localized area, significant variability has been observed, such as the order of magnitude variations observed across a 19 m long and 2 m deep portion of the Borden site (Canadian Forces Base, Ontario) [9-10]. Sorption processes also exert significant control over transport, but spatial variations in sorption properties are often neglected because they are cumbersome to measure.

Most groundwater modeling activities use average values for sorption parameters, such as the retardation coefficient, and these are normally based on either a limited number of measurements or estimates from bulk soil samples. Variations in sorption capacity can be especially important in the design of in situ remediation systems such as the biocurtain that was recently installed at the Schoolcraft site in Michigan [11- 14]. While the spatial variability of sorption parameters [15-18] and hydraulic conductivities [18-19] have been documented separately, very few studies have investigated whether they are correlated. Robin et al. [20-21] determined the distribution coefficients for strontium using aquifer material from the Borden site. Vertical and horizontal variability of distribution coefficients and hydraulic conductivity were studied along two orthogonal horizontal transects. They found very weak negative correlation between the two parameters. Because organic and inorganic chemicals are sorbed by different mechanisms, we have no theoretical basis to extrapolate these findings to organic contaminants [14-15]. Contaminated soil and groundwater poses a serious problem with respect to soil / ground water quality and the risk of spreading pollutants into other compartments of the environment. The major concern at most contaminated sites is the risk of groundwater pollution by organic and inorganic compounds [16-17]. Since the remediation of all contaminated sites is economically not feasible, ground water risk assessment procedures are needed for the ranking of sites, decision making on future use and remedial actions. At sites where petroleum products are handled or stored, contamination of the unsaturated soil zone is frequently found. Hydrocarbons can reach the ground water by transport with percolating water and by spreading in the soil gas. Degradation process can limit the spreading of the contaminants. The vadose zone usually consists of a heterogeneous geologic medium that provides crucial pollution protection to the groundwater through various physical, chemical, and biological processes. Vadose zone investigation provides valuable information regarding the source, extent, and strength of subsurface contamination, its (potential) impact on groundwater, and implications for remediation, such as evaluating the need and adequacy of certain remedial actions. Findings from vadose zone investigations also have important regulatory ramifications for identifying sources of groundwater contamination. Due to the importance of groundwater as a natural resource, a large number of studies on subsurface contamination were performed in the last decade. It became clear that there are significant uncertainties in the study of subsurface contaminations, especially those by toxic organic chemicals such as chlorinated solvents. These studies also highlighted the multidisciplinary nature of this particular environmental problem. There are a number of recent reviews on this topic, each with different emphases [11-15, 17- 20].

2. Governing Equation

$$SV\frac{d^2c}{dx^2} - QU\frac{dc}{dx} + Vt\frac{dc}{dx} = 0 \tag{1}$$

$$SV\frac{d^2c}{dx^2}(QV - Vt)\frac{dc}{dx} = 0 \tag{2}$$

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

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

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

$$SV\sum_{n=2}^{\infty} n(n-1) a_n x^{n-2} - QV - Vt\sum_{n=1}^{\infty} n a_n x^{n-1} = 0 \tag{3}$$

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

$$SV\sum_{n=0}^{\infty}(n+2)(n+1) a_{n+2} x^n - (QV - Vt)\sum_{n=0}^{\infty}(n+1) a_{n+1} x^n = 0 \tag{4}$$

i.e. $SV(n+2)(n+1) a_{n+2} = (QV - Vt)(n+1) an + 1 \tag{5}$

$$a_{n+2} = \frac{(QV - Vt)(n+1) a_{n+1}}{Sv(n+2)(n+1)} \tag{6}$$

$$a_{n+2} = \frac{(QV - Vt) a_{n+1}}{Sv(n+2)} \tag{7}$$

for $n = 0$, $a_2 = \frac{(QV - Vt) a_1}{2Sv} \tag{8}$

for $n = 1$, $a_3 = \frac{(QV - Vt)}{3Sv} = \frac{(QV - Vt)^2 a_1}{2Sv \bullet 3SV} \tag{9}$

$$\text{for } n = 2; a_4 = \frac{(QV - Vt)a_3}{4Sv} = \frac{(QV - Vt)}{4Sv} \bullet \frac{(QV - Vt)a_1}{3Sv \bullet 2Sv} = \frac{(QV - Vt)^3 a_1}{4Sv \bullet 3Sv \bullet 2Sv} \tag{10}$$

$$\text{for } n = 3; a_5 = \frac{(QV - Vt)}{5Sv} = \frac{(QV - Vt)^2 a_1}{5Sv \bullet 4 \bullet 3Svc \bullet 2Sv} \tag{11}$$

$$\text{for } n: a_n - \frac{(QV - Vt)^{n-1} a_1}{Sv^{n-1} n!} \tag{12}$$

$$C(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + a_5 x^5 + \ldots\ldots a_n x^n \tag{13}$$

$$= a_0 + a_1 x + \frac{(QV - Vt)a_1 x^2}{2!Sv} + \frac{(QV - Vt)a_1 + x^3}{3!Sv^2} + \frac{(QV - Vt)x^4 + (QV - Vt)}{4!Sv^3} + \ldots\ldots \tag{14}$$

$$C(x) = a_0 + a_1 \left[x + \frac{(OV - Vt)x}{2!Sv} + \frac{(Qv - Vt)x^3}{3!Sv^2} + \frac{(Qv - Vt)}{4!Sv^3} + \frac{(Qv - Vt)x^4}{5!Sv^4} \ldots \right] \tag{15}$$

$$C(x) = a_0 + a_1 \ell^{\frac{(Qv - Vt)}{Qv} x} \tag{16}$$

Subject to equation (16) to the following boundary conditions

$$C(o) = 0 \text{ and } C^1(o) = H$$

$$C(x) = a_o + a_1 \ell \left[\frac{Qv - Vt}{Sv} \right] x$$

$$C(o) = a_o + a_1 = o$$

$$\text{i.e. } a_o + a_1 = 0 \tag{17}$$

$$C^1(x) = \frac{(Qv - Vt)a_1}{Sv} \ell^{\frac{(Qv - Vt)}{Sv} x}$$

$$C^1(o) = \frac{(Qv - Vt)a_1}{Sv} = H$$

$$a_1 = \frac{HSv}{Qv - Vt} \tag{18}$$

$$a_i = -a_o$$

$$\Rightarrow a_o = -\frac{HSv}{(Qv - Vt)} \tag{19}$$

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

$$C(x) = -\frac{HSV}{Qv - Vt} + \frac{HSv}{Qv - Vt} \ell^{\frac{QV - Vt}{Qv} x}$$

$$\Rightarrow C(x) = \frac{HSv}{Vt - Sv} \left[\ell^{\frac{(Qv - Vt)}{Sv} x} {}_{-1} \right] \tag{20}$$

$$\text{If } x = V.t$$

$$\therefore C(x) = \frac{HSv}{Vt - Sv} \left[\ell^{\frac{(Qv - Vt)}{Sv} V.t} {}_{-1} \right] \tag{21}$$

$$\text{If } t = \frac{d}{v} \text{ similarly;}$$

$$C(x) = \frac{HSv}{Vt - Sv} \left[\ell^{\frac{(QV - Vt)}{Sv} \frac{d}{v}} {}_{-1} \right] \tag{22}$$

3. Materials and Method

Standard laboratory experiment where performed to monitor Ammonia concentration at different formation, the soil were collected in sequences base on the structural deposition at different locations, this samples collected at different location generate variation at different depth producing different accumulation of Ammonia concentration through column experiment, the experimental result are applied to be compared with the theoretical values in other to determined the validation of the model.

4. Result and Discussion

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

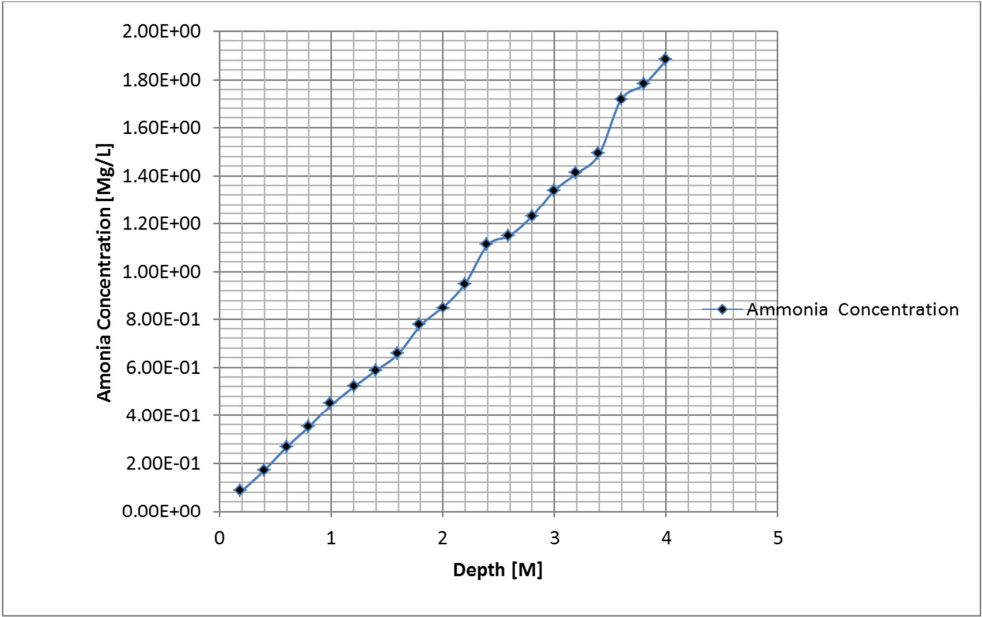**Figure 1.** *Predictive Values of Ammonia Concentration at Different Depth.*

Figure 2. *Predicted and Experimental values of Ammonia Concentration at Different Depth.*

Figure 3. *Predictive Values of Ammonia Concentration at Different Depth.*

Figure 4. *Predicted and Experimental values of Ammonia Concentration at Different Depth.*

Figure 5. *Predictive Values of Ammonia Concentration at Different Depth.*

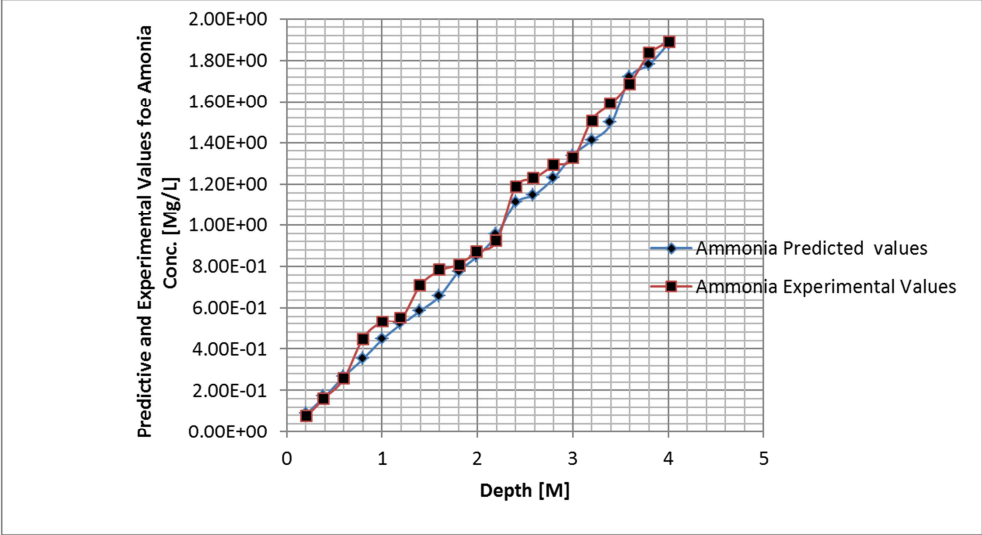**Figure 6.** *Predicted and Experimental values of Ammonia Concentration at Different Depth.*
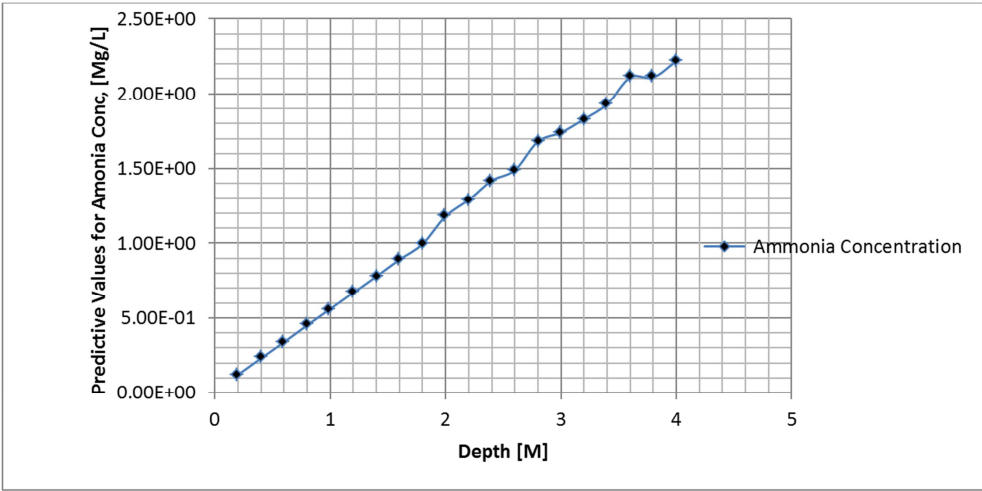
Figure 7. *Predictive Values of Ammonia Concentration at Different Depth.*
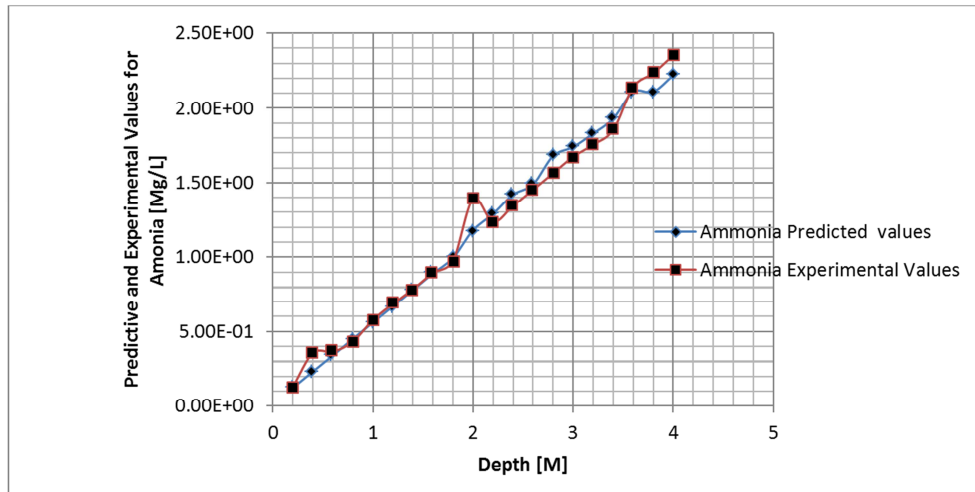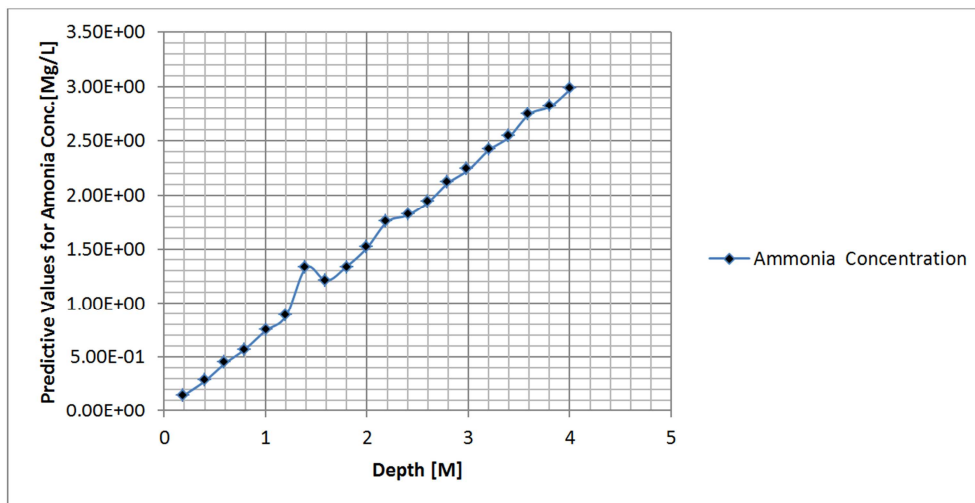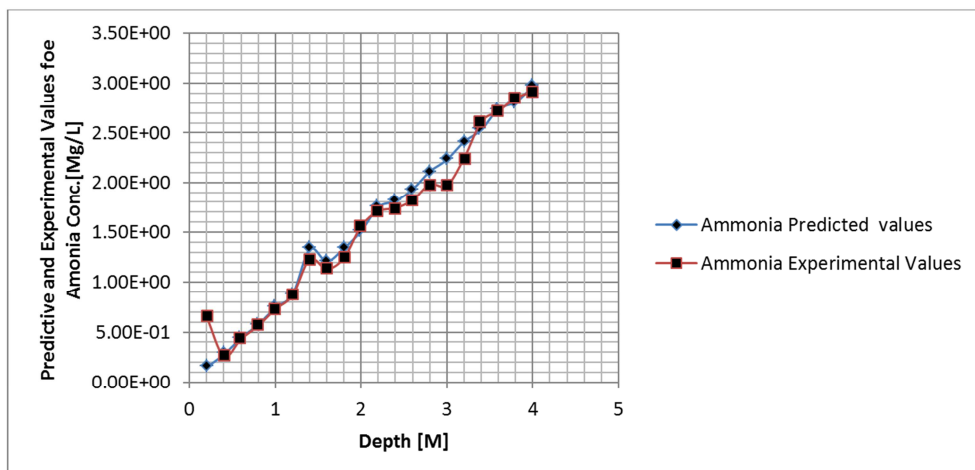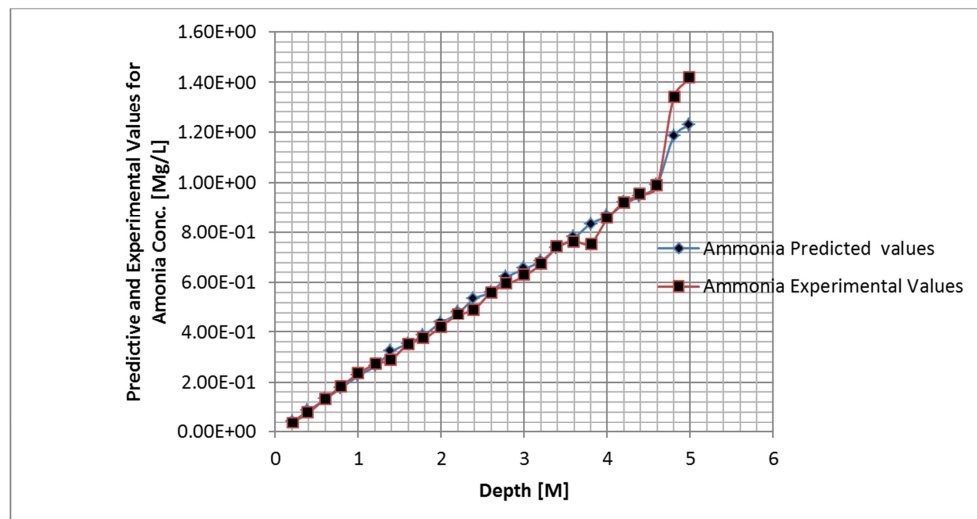

Figure 8. *Predicted and Experimental values of Ammonia Concentration at Different Depth.*
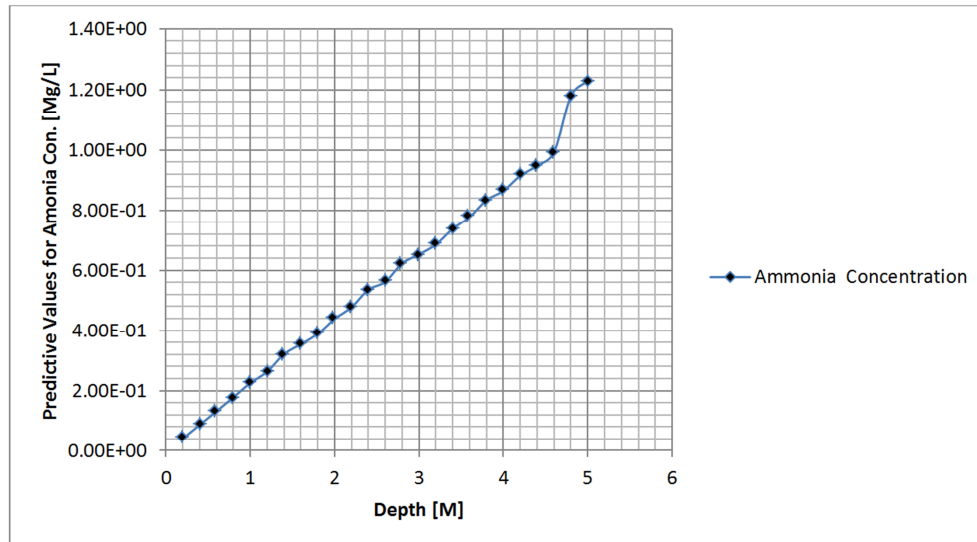
Table 1. *Predictive Values of Ammonia Concentration at Different Depth.*

Depth [M]	Ammonia Concentration
0.2	8.60E-02
0.4	1.71E-01
0.6	2.67E-01
0.8	3.512E-01
1	4.44E-01
1.2	5.19E-01
1.4	5.87E-01
1.6	6.56E-01
1.8	7.74E-01
2	8.51E-01
2.2	9.51E-01
2.4	1.11E+00
2.6	1.15E+00
2.8	1.23E+00
3	1.34E+00
3.2	1.41E+00
3.4	1.49E+00
3.6	1.72E+00
3.8	1.78E+00
4	1.88E+00

Table 2. *Predicted and Experimental values of Ammonia Concentration at Different Depth.*

Depth [M]	Ammonia Predicted values	Ammonia Experimental Values
0.2	8.60E-02	0.073
0.4	1.71E-01	0.165
0.6	2.67E-01	0.257
0.8	3.512E-01	0.45
1	4.44E-01	0.53
1.2	5.19E-01	0.55
1.4	5.87E-01	0.71
1.6	6.56E-01	0.78
1.8	7.74E-01	0.81
2	8.51E-01	0.87
2.2	9.51E-01	0.92
2.4	1.11E+00	1.19
2.6	1.15E+00	1.23
2.8	1.23E+00	1.29
3	1.34E+00	1.32
3.2	1.41E+00	1.51
3.4	1.49E+00	1.59
3.6	1.72E+00	1.69

Depth [M]	Ammonia Predicted values	Ammonia Experimental Values
3.8	1.78E+00	1.83
4	1.88E+00	1.89

Table 3. Predictive Values of Ammonia Concentration at Different Depth.

Depth [M]	Ammonia Concentration
0.2	1.22E-01
0.4	2.31E-01
0.6	3.39E-01
0.8	4.51E-01
1	5.60E-01
1.2	6.69E-01
1.4	7.79E-01
1.6	8.91E-01
1.8	9.95E-01
2	1.18E+00
2.2	1.29E+00
2.4	1.42E+00
2.6	1.49E+00
2.8	1.68E+00
3	1.74E+00
3.2	1.83E+00
3.4	1.93E+00
3.6	2.11E+00
3.8	2.11E+00
4	2.22E+00

Table 4. Predicted and Experimental values of Ammonia Concentration at Different Depth.

Depth [M]	Ammonia Predicted values	Ammonia Experimental Values
0.2	1.22E-01	0.129
0.4	2.31E-01	0.356
0.6	3.39E-01	0.365
0.8	4.51E-01	0.432
1	5.60E-01	0.577
1.2	6.69E-01	0.686
1.4	7.79E-01	0.785
1.6	8.91E-01	0.894
1.8	9.95E-01	0.976
2	1.18E+00	1.39
2.2	1.29E+00	1.236
2.4	1.42E+00	1.344
2.6	1.49E+00	1.453
2.8	1.68E+00	1.564
3	1.74E+00	1.674
3.2	1.83E+00	1.755
3.4	1.93E+00	1.854
3.6	2.11E+00	2.141
3.8	2.11E+00	2.234
4	2.22E+00	2.353

Table 5. Predictive Values of Ammonia Concentration at Different Depth.

Depth [M]	Ammonia Concentration
0.2	1.51E-01
0.4	2.78E-01
0.6	4.41E-01
0.8	5.75E-01
1	7.44E-01
1.2	8.79E-01
1.4	1.33E+00
1.6	1.21E+00

Depth [M]	Ammonia Concentration
1.8	1.34E+00
2	1.51E+00
2.2	1.75E+00
2.4	1.81E+00
2.6	1.93E+00
2.8	2.11E+00
3	2.23E+00
3.2	2.41E+00
3.4	2.53E+00
3.6	2.74E+00
3.8	2.81E+00
4	2.97E+00

Table 6. Predicted and Experimental values of Ammonia Concentration at Different Depth.

Depth [M]	Ammonia Predicted values	Ammonia Experimental Values
0.2	1.51E-01	0.65
0.4	2.78E-01	0.261
0.6	4.41E-01	0.431
0.8	5.75E-01	0.564
1	7.44E-01	0.728
1.2	8.79E-01	0.869
1.4	1.33E+00	1.23
1.6	1.21E+00	1.134
1.8	1.34E+00	1.243
2	1.51E+00	1.56
2.2	1.75E+00	1.71
2.4	1.81E+00	1.74
2.6	1.93E+00	1.82
2.8	2.11E+00	1.981
3	2.23E+00	1.969
3.2	2.41E+00	2.245
3.4	2.53E+00	2.61
3.6	2.74E+00	2.72
3.8	2.81E+00	2.85
4	2.97E+00	2.92

Table 7. Predictive Values of Ammonia Concentration at Different Depth.

Depth [M]	Ammonia Concentration
0.2	4.10E-02
0.4	8.66E-02
0.6	1.32E-01
0.8	1.78E-01
1	2.25E-01
1.2	2.63E-01
1.4	3.21E-01
1.6	3.54E-01
1.8	3.89E-01
2	4.39E-01
2.2	4.78E-01
2.4	5.36E-01
2.6	5.62E-01
2.8	6.23E-01
3	6.53E-01
3.2	6.86E-01
3.4	7.38E-01
3.6	7.78E-01
3.8	8.34E-01
4	8.65E-01
4.2	9.15E-01
4.4	9.48E-01
4.6	9.93E-01
4.8	1.18E+00
5	1.23E+00

Table 8. *Predicted and Experimental values of Ammonia Concentration at Different Depth.*

Depth [M]	Ammonia Predicted values	Ammonia Experimental Values
0.2	4.10E-02	0.0376
0.4	8.66E-02	0.0781
0.6	1.32E-01	0.134
0.8	1.78E-01	0.184
1	2.25E-01	0.234
1.2	2.63E-01	0.271
1.4	3.21E-01	0.291
1.6	3.54E-01	0.351
1.8	3.89E-01	0.374
2	4.39E-01	0.422
2.2	4.78E-01	0.469
2.4	5.36E-01	0.494
2.6	5.62E-01	0.561
2.8	6.23E-01	0.594
3	6.53E-01	0.626
3.2	6.86E-01	0.673
3.4	7.38E-01	0.742
3.6	7.78E-01	0.764
3.8	8.34E-01	0.756
4	8.65E-01	0.854
4.2	9.15E-01	0.923
4.4	9.48E-01	0.951
4.6	9.93E-01	0.986
4.8	1.18E+00	1.34
5	1.23E+00	1.415

Generated results has provided different rate of Ammonia concentration at different depth, these were observed from the simulation values through graphical representation expressed from the developed model, slight heterogeneous depositions of the contaminant was observed from the entire figures from the graphical representation. Ammonia transport in silty clay formation, figure one and two deposited in homogeneous setting under exponential phase, these are base on the structural setting of the deltaic formation, and the silty clay depositions were observed in a high content in predominant clay minerals that developed low void ratio and porosity between the stratums in the environment. Like figure and two the concentration are from 0.0860-1.88mg/L, such condition affect the deposition of ammonia depositions in the study location, the concentration transport from low to optimum level at four metres recorded in hose locations figure three and four expressed higher accumulation of Ammonia in the silty clay deposition, the lowest were recorded at 0.122 -1.22mg/l. while figure five and six express more accumulation compare to three and four, the lowest deposited at 00.115mg/l. while the highest recorded at 2.97mg/l. This condition can be attributed to the high clay content that has reduced the permeation of the soil, these will definitely generate accumulation of the substances, figure seven and eight express lower accumulation of lead compare to other substances deposited in the environment, the lowest recorded at 0.0410 mg/l while the optimum were observed at 1.23 Mg /l, the behaviour of all the deposited substances were pressured by impermeable deposition in silty clay formation, the developed model generated theoretical values, these were compared with experimental data, both

parameters express best fits validating the developed model for the study.

5. Conclusion

Accumulation of Ammonia in silty clay formation has been expressed applying this type of mathematical techniques, the study were to monitor the rate accumulation of ammonia in silty clay formation applying this concept, this application has not been applied thoroughly in soil sequences by other experts to generate the accumulation of Ammonia in silty clay depositions, numerous experts have apply lots of empirical concept to determine the rate of concentration of Ammonia in soil depositions, the rate of accumulation were generated through the simulation values, the model can predict any level of Ammonia accumulation in lateritic and other soil formation, the generated values were compared with experimental data and both parameters express faviourable fits validating the developed model for the study.

References

[1] Xianda Zhao Roger B. Wallace a, David W. Hyndman Michael J. Dybas Thomas C. Voice Heterogeneity of chlorinated hydrocarbon sorption properties in a sandy aquifer Journal of Contaminant Hydrology 78 (2005) 327– 342.

[2] Rao, P. S. C., et al., 1986. Spatial variability of pesticide sorption and degradation parameters. ACS Symp. Series 315, 100–115.

[3] Rehfeldt, K. R., Boggs, J. M., Gelhar, L. W., 1992. Field study of dispersion in a heterogeneous aquifer 3. Geostatistical analysis of hydraulic conductivity. Water Resour. Res. 28 (12), 3309–3324.

[4] Robin, M. J. L., Sudicky, E. A., Gillham, R. W., Kachanoski, R. G., 1991. Spatial variability of strontium distribution coefficients and their correlation with hydraulic conductivity in the Canadian Forces Base Borden aquifer. Water Resour. Res. 27 (10), 2619–2632.

[5] Hyndman, D. W., Dybas, M. J., Forney, L., Heine, R., Mayotte, T., Phanikumar, M. S., Tatara, G., Tiedje, J., Voice, T., Wallace, R., Wiggert, D., Zhao, X., Criddle, C. S., 2000. Hydraulic characterization and design of a fullscalebiocurtain. Ground Water 38 (3), 462– 474.

[6] Pickens, J. F., Jackson, R. E., Inch, K. J., Merritt, W. F., 1981. Measurement of distribution coefficients using a radial injection dual-tracer test. Water Resour. Res. 17 (3), 529– 544.

[7] Dybas, M. J., et al., 2002. Development, operation and long-term performance of a full-scale biocurtain utilizing bioaugmentation. Environ. Sci. Technol. 36 (16), 3635– 3644.

[8] Elabd, H., Jury, W. A., Cliath, M. M., 1986. Spatial variability of pesticide adsorption parameters. Environ. Sci. Technol. 20 (3), 256– 260.

[9] Mackay, D. M., Ball, W. P., Durant, M. G., 1986. Variability of aquifer sorption properties in a field experiment on groundwater transport of organic solutes: methods and preliminary results. J. Contam. Hydrol. 1 (1–2), 119– 132.

[10] Wood, L. S., Scott, H. D., Marx, D. B., Lavy, T. L., 1987. Variability in sorption coefficients of metolachlor on a Captina silt loam. J. Environ. Qual. 16 (3), 251– 256.

[11] Robin, M. J. L., Sudicky, E. A., Gillham, R. W., Kachanoski, R. G., 1991. Spatial variability of strontium distribution coefficients and their correlation with hydraulic conductivity in the Canadian Forces Base Borden aquifer. Water Resour. Res. 27 (10), 2619–2632.

[12] Oluwapelumi. O. O Samuel. A. O (2010) Plume Behaviour for Petroleum Hydrocarbon in a Tropical Sand Tank: Laboratory Experiments and Scenario-Specific Modeling European Journal of Scientific Research Vol. 39 No. 4 pp. 523-541.

[13] Grathwohl, P. & I. Klenk, 2000. ―Groundwater risk assessment at contaminated sites‖ (GRACOS). In: Contaminated Soil 2000 vol. 2 (ed. By W. Harder et al.) pp 831-834. Thomas Telford, Leipzig, Germany.

[14] Jury, W. A. and Flühler, H. 1992. Transport of chemicals through soil: mechanisms, models, and field applications. Adv. Agron. 47: 141–201.

[15] D. R., van Genuchten, M. Th., and Biggar, J. W. 1986. Water flow and solute transport processes in the unsaturated zone. Water Resour. Res. 22 (9): 89S–108S.

[16] Schwille, F. 1984. Migration of organic fluids immiscible with water in the unsaturated zone.

[17] Yaron, B. et al., 1994 Pollutants in Porous Media, The Unsaturated Zone Between Soil Surface and Groundwater. Berlin, Springer-Verlag.

[18] USEPA. 1989. Seminar Publication, Transport and Fate of Contaminants in the Subsurface. EPA/ 625/4-89/019. September 1989.

[19] USEPA. 1990. Handbook, Ground Water, Vol. 1, Ground Water and Contamination. EPA/625/6-90/ 016a. September 1990 USEPA. 1991. Ground Water Issue — Dense Nonaqueous Phase Liquids. EPA/540/4-91-002. March 1991.

[20] Samuel C. T. Yu, D. Env. Transport and Fate of Chlorinated Hydrocarbons in the Vadose Zone — a Literature Review with Discussions on Regulatory Implications Journal of Soil Contamination, 3 (4): (1994).

[21] Eluozo S. N (2012) Mathematical modeling of unsaturated soil multiflow assessment on hydrocarbon contamination in coastal area of okirika, rivers state of Nigeria unpublished article in press.