Research Open Journal of Civil Engineering
Vol. 1, No. 1, January 2014, PP: 01-13
Available online at http://scitecpub.com/Journals.php

Research article

SIMULATION OF SHIGELLAE TRANSPORT INFLUENCED BY AMMONIA AND HOMOGENEOUS POROSITY IN PERCH AQUIFEROUS ZONE IN ABOLUMA DISTRICT OF PORT HARCOURT METROPOLIS, RIVERS STATE OF NIGERIA

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Abstract

Simulating the developed model for Shigellae deposition and migration in the study environments was to ensure that the rates of concentration are monitored. Influences from high degree of porosity has been confirmed to have cause fast migration and regeneration of the microbes in the study area, the simulation of the model generated theoretical values compared with experimental values, both parameters developed a favuorable fits validating the developed mathematical model, the expression from the resulted represented graphically shows exponential phase in linear condition, but the rate of concentration deposited variation at various depths at different location, such change in concentration are influenced by the rates of fluctuation of ammonia deposition at various strata, the developed model expressed the rates of influences from ammonia deposition in the formation, such influences increase the deposition of Shigellae in the study area, experts will definitely applied this model to monitor the rate of Shigellae migration from perch to unconfined bed.

Keywords: simulation, Shigellae transport ammonia influences and perch aquiferous zone

1. Introduction

In many parts of sub-Saharan Africa, hydrogeologic data are sparse and difficult to access. One example is the Nigeria geological formations including other countries geological history like Keta Basin of southeastern

Ghana and the Coastal Sedimentary Basin of Togo. Existing data quality on groundwater flow patterns and hydrodynamic aquifer characteristics from this region is weak, and subsurface geology is poorly understood in many parts of the region. In the present study, hydrochemistry and isotope geochemistry are applied to obtain hydrogeological information from the area in spite of lack of basic data on groundwater flow patterns and aquifer characteristics (Tina, 2006). In regard to permeability predictions, Koltermann and Gorelick (1995) modified the Kozeny-Carman equation to better represent sediment mixtures by incorporating their fractional packing model for porosity. Kamann (2004) measured porosity and permeability on sediment mixtures and then compared these to values predicted by the models mentioned above. These mixtures were model approximations of natural poorly-sorted sands and sandy gravels. The introduction of five possible types of packing that can occur in a sediment mixture accounts for complex packing arrangements that may be present naturally. Therefore, Kamann (2004) assumed that the expanded fractional packing model is generally representative of poorly- sorted sands and sandy gravels. The present study will evaluate how well the model applies to natural sediment. Taking the results and procedures of Kamann (2004) into account, Conrad (2006) focused further on the permeability of bimodal sediment mixtures by taking measurements at small support scales. Conrad (2006) revised the air-based permeability procedures of Kamann (2004) to reduce displacement of sediment by air slip-flow. Conrad (2006) determined a sufficient depth in the sediment at which a stable representative measurement could be taken, which he termed the tip-seal burial method. He also improved upon the correction needed for the air- based measurements to account for the effects of high-velocity flow. He repeated the permeability measurements taken by Kamann (2004) and further confirmed the applicability of the permeability model. Conrad (2006) found that the air-based measurements corresponded well to the water-based measurements for both sand mixtures and sand/pebble mixtures. Thus, the air-based measurements with a small support scale were generally similar to the water based measurements with a larger support scale. Conrad (2006) concluded that the permeability of bimodal sediment mixtures of poorly-sorted sands can be accurately measured with the air-based permeameter. He found that mixtures dominated by finer grains show only subtle differences between air- and water-based measurements. Conrad (2006) determined that the air-based permeameter captures subtle changes in poorly sorted sands better than in pebbly sands. In addition to Kamann (2004) and Conrad (2006), studies have been conducted since the work of Koltermann and Gorelick (1995) that utilize models for predicting permeability. Revil and Cathles (1999) presented a permeability model for bimodal sediment mixtures that is based on parameters that separate pore throat porosity from total porosity and the effective radius from the total radius of the grains. Boadu (2000), developed permeability model using representations of the grain size distribution as well as the petrophysical properties of porosity, volume fraction of fines, and bulk density. Other research on the porosity- permeability relationship for porous media involved the modification of previous models (Barr (2001), Revil et al. (2002), Chapuis and Aubertin (2003), Chapuis (2004), and Costa (2006)). These studies all use different models for predicting permeability but none of them utilize a fractional packing model for porosity. Model sediment mixtures and predicted porosity values are useful tools for testing the applicability of a permeability model. Therefore, the research conducted by Kamann (2004) provides results that can be applied to other permeability models. This study will take the necessary step of testing his model to determine if it is accurate for natural sediment, which will help improve confidence in its applicability (Peter, 2005, Eluozo, 2013).

2. Governing Equation

$$\phi \frac{\partial c_3}{\partial t} = K_c \frac{\partial c_3}{\partial x} \quad \ldots\ldots\ldots\ldots\ldots \tag{1}$$

Let $C_3 = TX$

$$\frac{\partial c_3}{\partial t} = XT^1 \quad \ldots\ldots\ldots\ldots\ldots \tag{2}$$

$$\frac{\partial c_3}{\partial x} = X^1 T \quad \ldots\ldots\ldots\ldots\ldots \tag{3}$$

$$\phi T^1 X = KX^1 T \quad \ldots\ldots\ldots\ldots\ldots \tag{4}$$

$$\phi \frac{T^1}{T} = K_c \frac{X^1}{X} = \varphi^2 \quad \ldots\ldots\ldots\ldots\ldots \tag{5}$$

$$\phi \frac{T^1}{T} = \varphi^2 \quad \ldots\ldots\ldots\ldots\ldots \tag{6}$$

$$\frac{T^1}{T} = \frac{\varphi}{\phi} \quad \ldots\ldots\ldots\ldots\ldots \tag{7}$$

$$LnT = \frac{\varphi^2}{\phi} t + a_4 \quad \ldots\ldots\ldots\ldots\ldots \tag{8}$$

i.e. $T = C_4 \ell^{\frac{\varphi^2}{\phi} t}$ .... (9)

$$T = \ell^{\frac{\varphi^2}{\phi} t} \quad \ldots\ldots\ldots\ldots\ldots \tag{10}$$

$$\phi \frac{T^1}{T} = K_c \frac{X^1}{X} = \varphi^2 \quad \ldots\ldots\ldots\ldots\ldots \tag{11}$$

$$\frac{dx}{dx} - \frac{\varphi^2}{Kc} x = 0 \quad \ldots\ldots\ldots\ldots\ldots \tag{12}$$

Auxiliary equation

$$M^2 - \varphi^2 = 0 \quad \ldots\ldots\ldots\ldots\ldots \tag{13}$$

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$$M = \pm i \frac{\varphi}{\sqrt{Kc}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(14)}$$

$$X = K_c \, \ell^{\frac{\varphi}{Kc}x} + E \, \ell^{\frac{-\varphi}{Kc}x} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(15)}$$

Combining (10) and (15) yield

$$C_3 = TX$$

i.e. $C_3 = C_4 \, \ell^{\frac{\varphi}{\phi}t} \left(K_c \frac{\varphi}{\sqrt{Kc}} x + E\ell^{\frac{-\varphi}{\sqrt{Kc}}x} \right)$ ………………………… (16)

The generated expressed model at this stage shows the level of inhibition that may be establish on the process of deposition in some region of the soil structure, it may deposit transitory flow base on minor deposition of porosity reflecting on the speed of transport flow. The percentage of porosity in this condition determine the tempo of inhibition from arsenic and fungi at this phase of the migration process, the pressure from degree of porosity strong-minded the deposition of arsenic and other substances inhibiting microbes in the stratification of the soil structure

Let $C = TY$ ………………………… (17)

$$\frac{\partial c}{\partial t} = T^1 Y \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(18)}$$

$$\frac{\partial^2 c}{\partial y^2} = TY^{11} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(20)}$$

$$\phi T^1 Y = K_d \, TY^{11} = \alpha^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(21)}$$

$$\int \frac{dT}{T} = \int \frac{-\alpha^2}{\phi} dt \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(22)}$$

$$LnT = \frac{-\alpha^2}{\phi} t + a_5 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(23)}$$

$$T = \ell^{\frac{-\alpha^2}{\phi}t + a_5} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(24)}$$

$$T = C_4 \, \ell^{\frac{-\alpha^2}{\phi}t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(25)}$$

$$K_d \frac{Y^{11}}{Y} = -\alpha^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(26)}$$

$$\frac{\partial^2 y}{\partial y^2} + \frac{\alpha^2}{K_d} y = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (27)$$

Auxiliary equation is

$$M^2 + \frac{\alpha^2}{K_d} = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (28)$$

$$M = \pm i \frac{\alpha}{\sqrt{K_d}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (29)$$

$$\therefore Y = A Cos \frac{\alpha}{\sqrt{K_d}} X + B Sin \frac{\alpha}{\sqrt{K_d}} X \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (30)$$

Combine (25) and (30), we have

$$C_4 = TY$$

$$C_4 = C_5 \, \ell^{\frac{-\alpha^2}{\phi} t} \left(A Cos \frac{\alpha}{\sqrt{K_d}} X + A Sin \frac{\alpha}{\sqrt{K_d}} X \right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (31)$$

3. Materials and method

Soil samples from several different boring locations, were collected at intervals between two and three meters each. Soil sample were collected in five different location, applying insitu method of sample collection, the soil sample were collected for analysis, standard laboratory analysis were carried out to determine the Shigellae concentration through column experiment, the result were analyzed to determine the influence on Shigellae in perched aquifers transport in the study area.

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 Shigellae at Different Depths

Depths [M]	Concentration
3	0.08
6	0.17
9	0.25
12	0.34
15	0.42
18	0.51
21	0.6
24	0.68

27	0.77
30	0.85

Table 2: Concentration of Shigellae at Different Time

Time Per Day	Concentration
10	0.08
20	0.17
30	0.25
40	0.34
50	0.42
60	0.51
70	0.6
80	0.68
90	0.77
100	0.85

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

Depths [M]	Theoretical Values	Experimental Values
3	0.08	0.07
6	0.17	0.15
9	0.25	0.23
12	0.34	0.32
15	0.42	0.4
18	0.51	0.49
21	0.6	0.58
24	0.68	0.66
27	0.77	0.75
30	0.85	0.83

Table 4: Comparison of Theoretical and Experimental Values of Shigellae concentration at Different Time

Time Per Day	Theoretical Values	Experimental Values
10	0.08	0.07
20	0.17	0.15
30	0.25	0.23
40	0.34	0.32
50	0.42	0.4
60	0.51	0.49
70	0.6	0.58
80	0.68	0.66

90	0.77	0.75
100	0.85	0.83

Table 5: Concentration of Shigellae at Different Depths

Depths [M]	Concentration
2	0.09
4	0.11
6	0.17
8	0.22
10	0.28
12	0.34
14	0.4
16	0.46
18	0.51
20	0.57

Table 6: Concentration of Shigellae at Different Depths

Time Per Day	Concentration
2	0.09
4	0.11
6	0.17
8	0.22
10	0.28
12	0.34
14	0.4
16	0.46
18	0.51
20	0.57

Table 6: Comparison of Theoretical and Experimental Values of Shigellae concentration at Different Time

Depths [M]	Theoretical Values	Experimental Values
2	0.09	0.07
4	0.11	0.1
6	0.17	0.15
8	0.22	0.2
10	0.28	0.26
12	0.34	0.32
14	0.4	0.38
16	0.46	0.44
18	0.51	0.49

20	**0.57**	**0.55**

Table 8: Comparison of Theoretical and Experimental Values of Shigellae concentration at Different Time

Time Per Day	Theoretical Values	Experimental Values
2	0.09	0.07
4	0.11	0.1
6	0.17	0.15
8	0.22	0.2
10	0.28	0.26
12	0.34	0.32
14	0.4	0.38
16	0.46	0.44
18	0.51	0.49
20	0.57	0.55

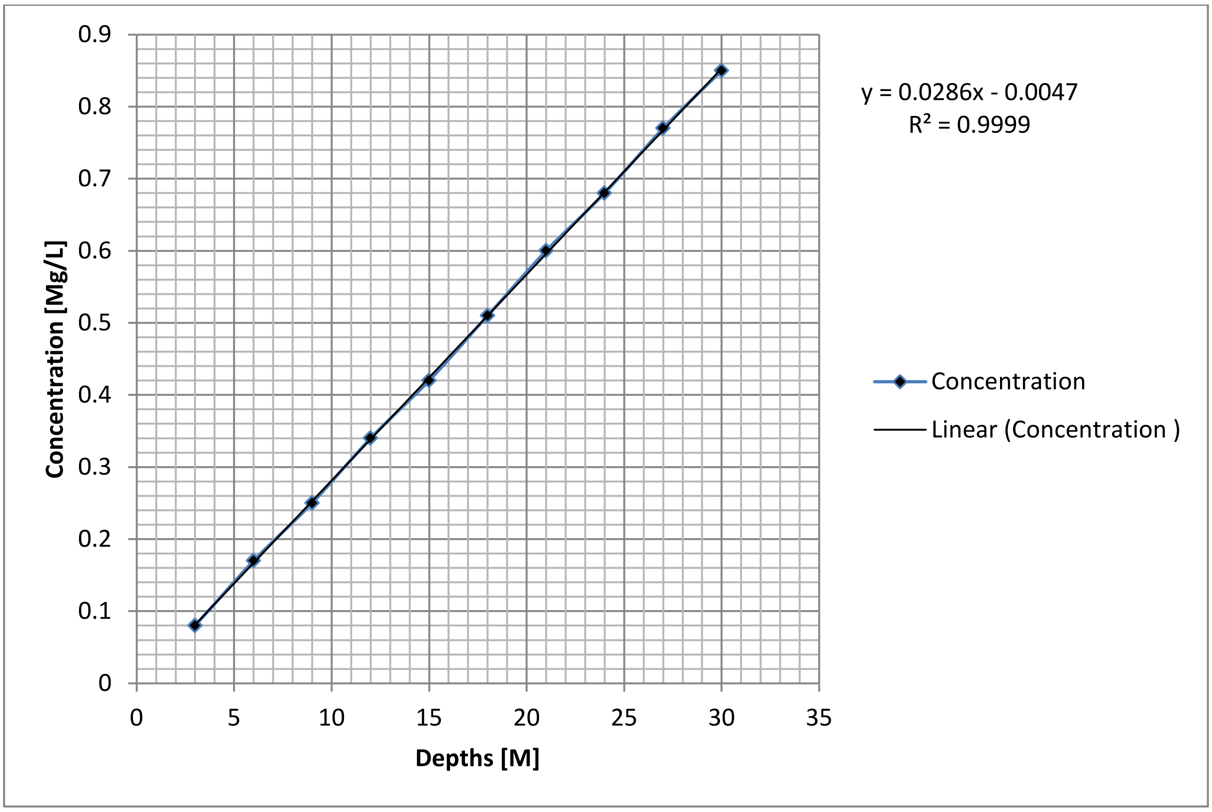

Figure 1: Concentration of Shigellae at Different Depths

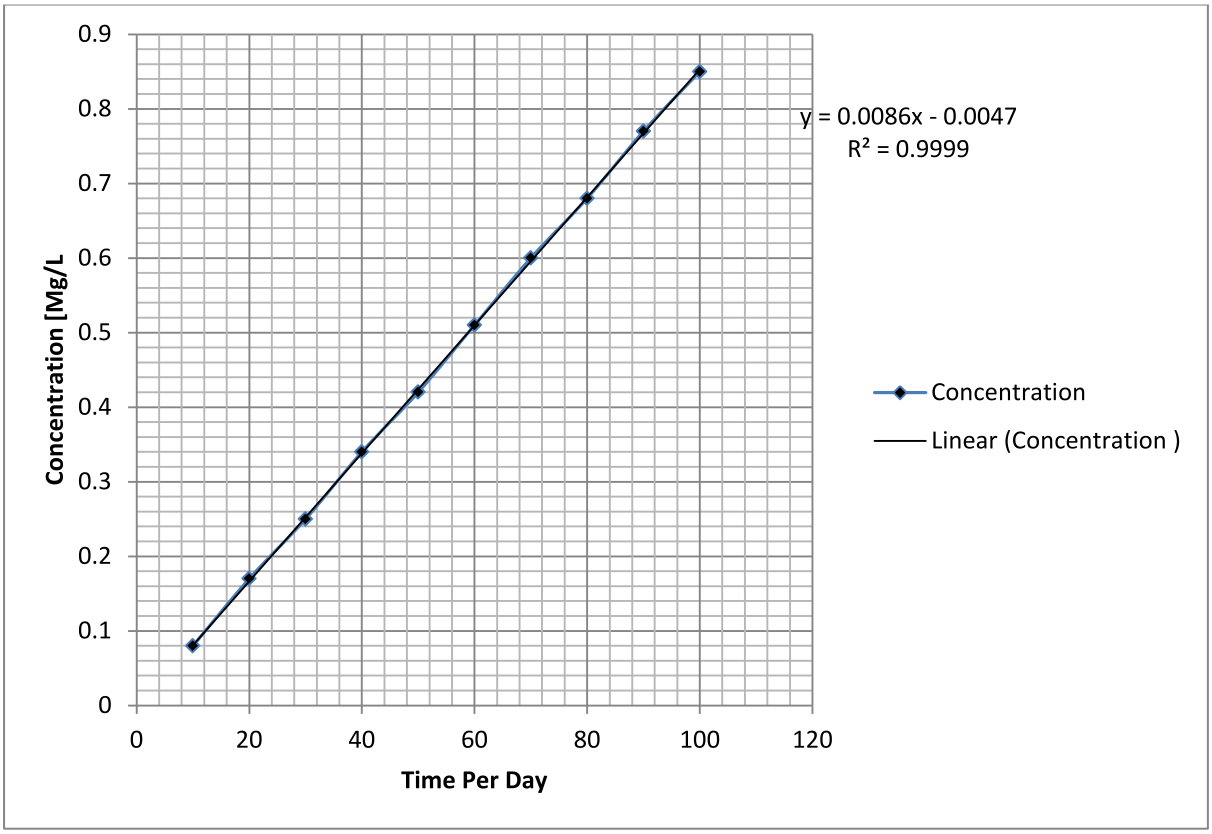

Figure 2: Concentration of Shigellae at Different Depths

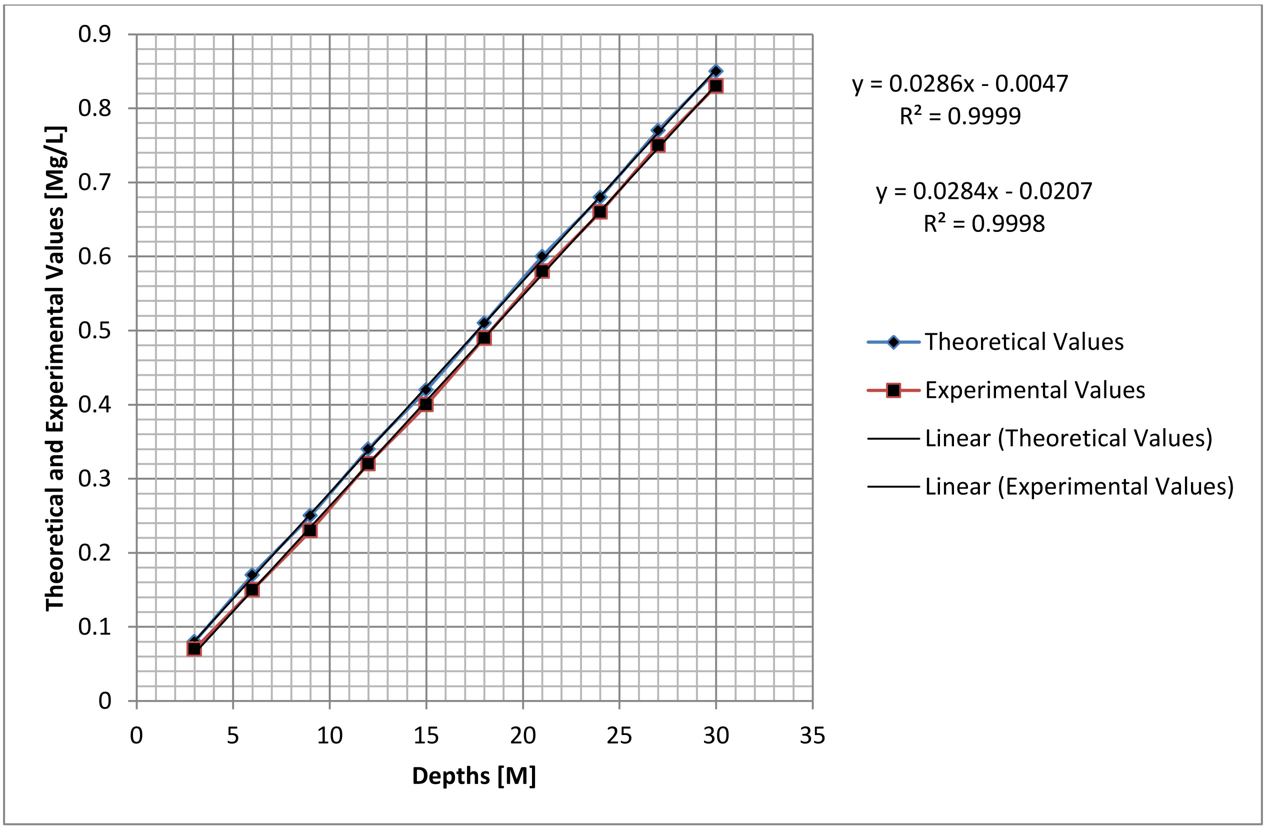

Figure 3: Comparison of Theoretical and Experimental Values of Shigellae concentration at Different Depths

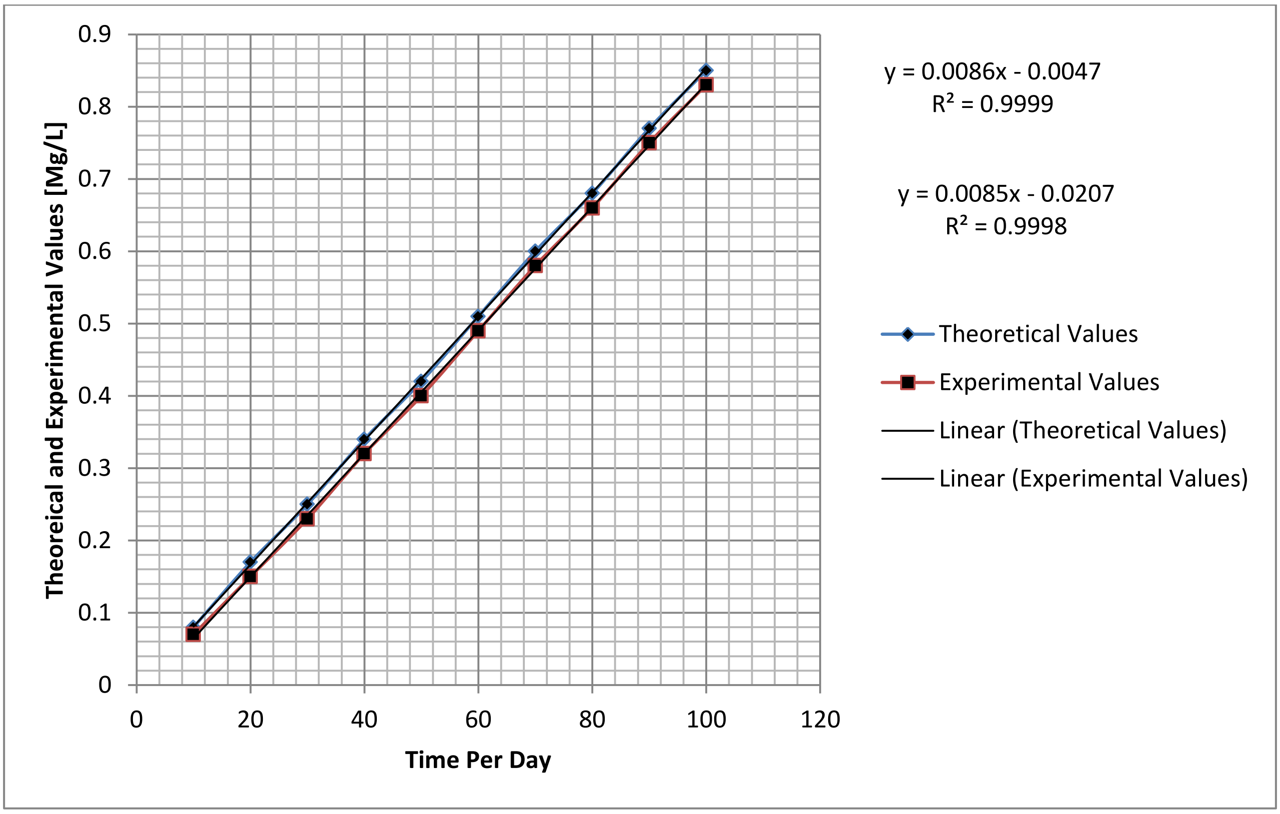

Figure 4: Comparison of Theoretical and Experimental Values of Shigellae concentration at Different Time

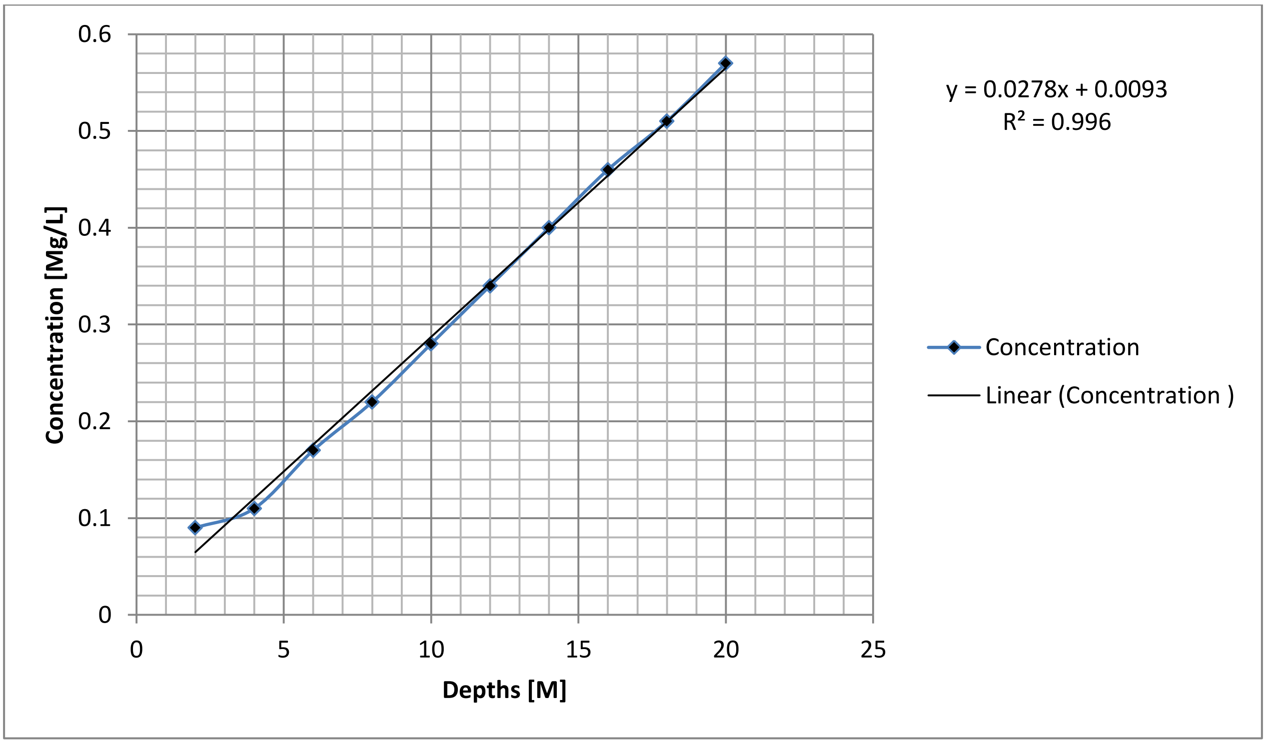

Figure 5: Concentration of Shigellae at Different Depths

Research Open Journal of Civil Engineering
Vol. 1, No. 1, January 2014, PP: 01-13
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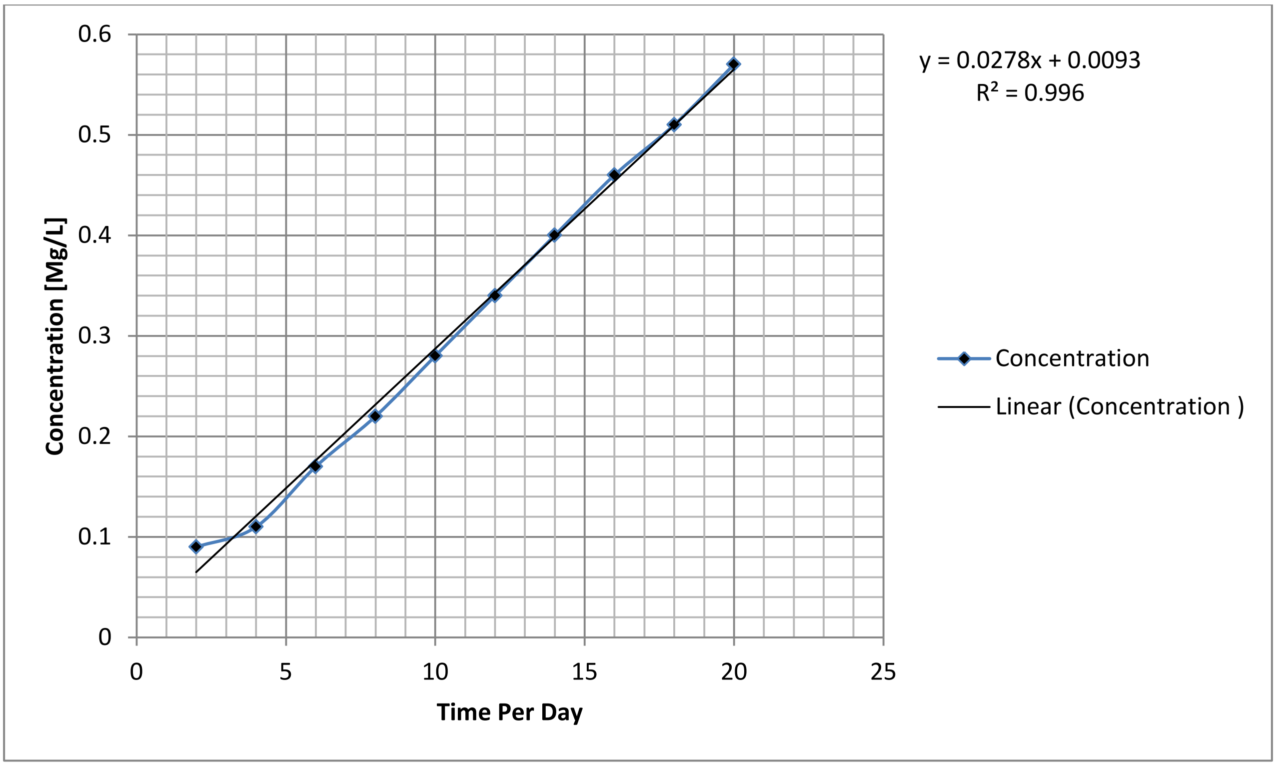

Figure 6: Concentration of Shigellae at Different Time

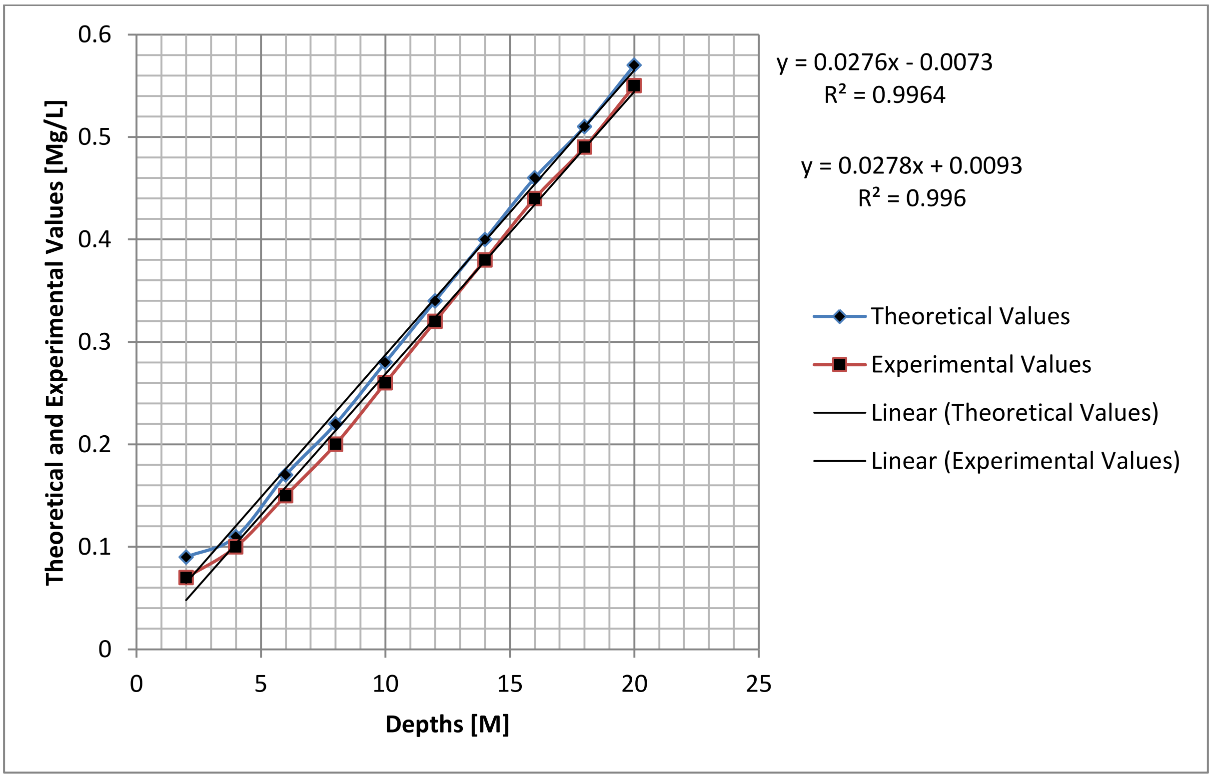

Figure 7: Comparison of Theoretical and Experimental Values of Shigellae concentration at Different Time

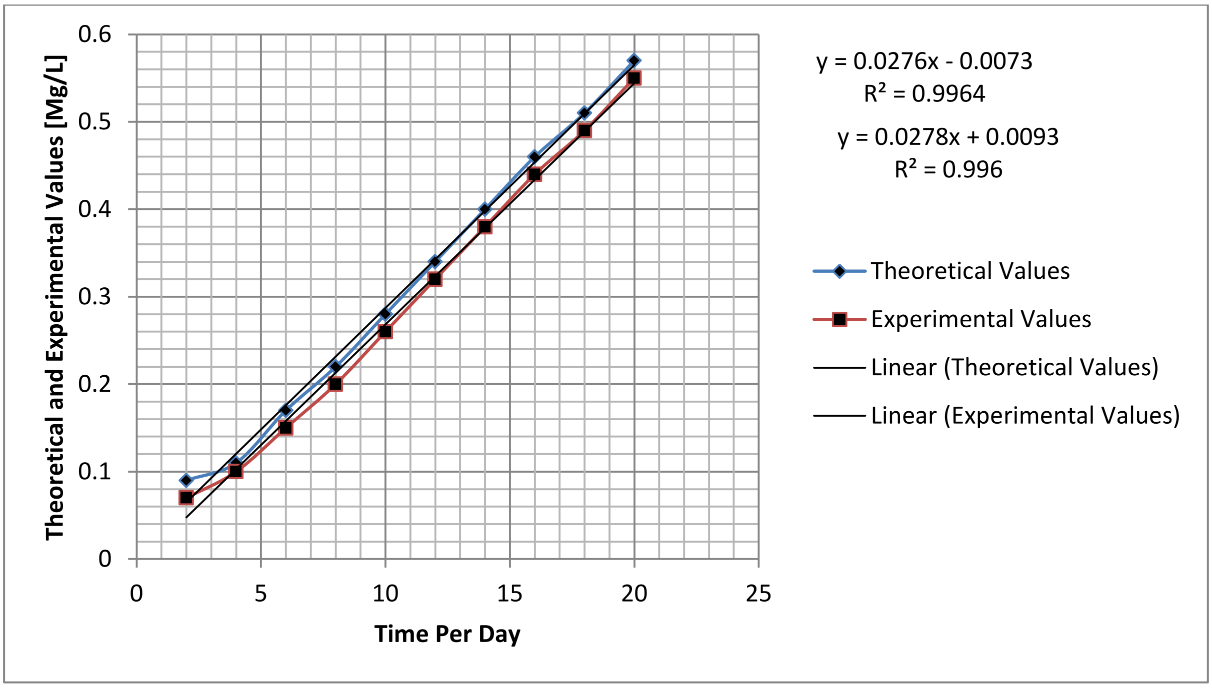

Figure 8: Comparison of Theoretical and Experimental Values of Shigellae concentration at Different Time

Figure [1-8] shows simultaneous representation of the Shigellae deposition in the study location, such linear condition has lots of implication under the influences of structural stratification of the formation. The deposition of the microbes, despites linear phase of Shigellae develops lots of variation in the study environments, the structure of the formation were found to deposit predominant deposition of porosity expressing fast migration of Shigellae in the study area, the rates of concentration migrating at different level can be attributed to variation of porosity, but the stratification of the formation deposit homogeneous velocity influencing permeability as it is experienced from the variation of concentration under linear condition. simulation of this model express the deposition and migration process of Shigellae, these were to monitor the concentration at different location in the study area, optimum values deposited in the region of the formation express degree of porosity are very high level, the formation experiences higher hydraulic conductivity also in the study are, theoretical values were compared with experimental values, both parameters compared faviourably well expressing the validation of the developed model.

4. Conclusion

The deposition of Shigellae in the study location develop lots of soil and water pollution in the study area, such condition were investigated in the study environment, it was discovered that Shigellae was the predominant contaminant with high degree of porosity in the formation, previous investigation could not provide any concrete solution, the contaminant keeping on increasing in the formation under the influences of high degree of porosity including other deposited minerals that could increase its population, such pollution is of serious concern in the study area, because of health implications it has on the study environment, depositing in perch aquifers in the study area implies that it will continue to accumulate with the pressure from high degree of porosity and will finally migrate fast to unconfined bed the study area, it is imperative because the rate of

Shigellae migration has generate lots of tension of quality water pollution caused by this types of contaminant in the study environments. The theoretical results generated were compared with experimental values, both parameters develop a favuorable fits validating the developed model, experts will applied this developed mathematical tools to monitor the deposition and migration of Shigellae in the study environments.

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