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Modelling and Simulation to Monitor Porosity Effect on Phosphorus Deposition in a Uniform Fine Sand Formation, Sapelle, Delta State of Nigeria

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Abstract: The paper investigate the deposition of phosphorus through the lithology of the environment, thus examine their transport processes, it also expresses the behaviour of the micronutrient in uniform coarse formation, the rate of migration was monitored in terms of the concentrations in predominant homogeneous fine sand formations, this study was found imperative because of high rate of phosphorus concentration at different predominant homogeneous depositions, such conditions were critically evaluated to determine the cause of fast deposition and migration, the derived model was generated through the developed governing equation, the developed model was simulated to produce theoretical values, the system generated several linearized migrating processes, but with different concentrations. The theoretical values were compared with experimental data for model validation, both parameters express favourable fits, the study is imperative because the uniformity of fine sand formation has generated various rate of concentration including their transport processes. Experts will definitely apply this concept to observe various rate of phosphorus concentration in soil and water environment.

Keywords: Modelling and Simulation, Porosity, Phosphorus, Fine Formation

1. Introduction

Water crisis. Worldwide, the demand on fresh water resources is increasing, already reaching the level of acute crisis in many regions [1-3]. These are due to the increasing demands of rising populations, speedy urbanisation and growing water utilization for agricultural and industrial manufacture. This is compounded by recoil water resources brought about by variation in climatic conditions leading to temperature increase and deteriorating of rainfall. This causes long-lasting drought periods, during which surface water reservoirs are no longer able to match water demand [2-3]. Excessive groundwater abstraction generates water table drawdown, these conditions opens the door to compounding environmental problems such as land subsidence and saltwater intrusion [5-8]. Certain environmental situations, such as the dependence of large urban settlements on a single river (for example, some developed country like London provided drinking water mainly from the river Thames), more so, little landmass or absent natural aquifers can exacerbate the water scarcity further [10-11]. With surface and groundwater sources increasingly failing to provide a durable, continuous supply, water reuse in an unnaturally shortened water cycle is rapidly becoming more important for realistic water resources management [12-15]. While water recycling for non-potable purposes (e.g. irrigation of agricultural fields, parks and golf courses, it is observed that process water in industrial contexts or water for toilet flushing in households) are mainly established today [2-3], so-called indirect potable water reuse is on increment is imperative [14]. Natural water always contains substances in suspended or particular form. Some of them are favourable, such as minerals that give spring water a certain distinct taste [3]. However, natural waters are often a habitat for microbial organisms, many of them harmful to human health. The WHO estimates roughly 10% of the global disease burden would be preventable by improving water supply, sanitation, hygiene and the management of water resources [15-17]. However, in the last decade's so-called xenobiotics substances, meaning chemicals not naturally occurring in the environment, increasingly came into focus. Firstly, pesticides were recognised as possible threats to water quality [11-14]. Due to better analytical instrumentation allowing the detection of polar substances in the mg/L range, a group of "emerging" organic micro pollutants was noticed in the 1990s, among them pharmaceuticals [9-12, 15-17].

2. Governing Equation

$$K_t \frac{d^2c}{dz^2} - aL\frac{dc}{dz} + \frac{v}{R}\frac{dc}{dz} = 0 \quad (1)$$

$$K_t \frac{d^2c}{dz^2} - \left(aL - \frac{v}{R}\right)\frac{dc}{dz} = 0 \quad (2)$$

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

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

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

$$K_t \sum_{n=2}^{\infty} (n-1) a_n x^{n-2} - \left(aL - \frac{v}{R}\right)\sum_{n=1}^{\infty} n a_n x^{n-1} = 0 \quad (3)$$

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

$$K_t \sum_{n=2}^{\infty} (n+2)(n+1) a_{n+2} x^n - \left(aL - \frac{V}{R}\right)\sum_{n=0}^{\infty} (n+1) a_{n+1} x^n = 0 \quad (4)$$

$$\text{i.e. } K_t (n+2)(n+1) a_{n+2} = \left(aL - \frac{V}{R}\right)(n+1) a_{n+1} \quad (5)$$

$$a_{n+2} = \frac{\left(aL - \frac{V}{R}\right)(n+1) a_{n+1}}{K_t (n+2)(n+1)} \quad (6)$$

$$a_{n+2} = \frac{\left(aL - \frac{V}{R}\right) a_{n+1}}{K_t (n+2)} \quad (7)$$

$$\text{for } n = 0,\ a_2 = \frac{\left(\varphi - \frac{V}{R}\right) a_1}{2K_t} \quad (8)$$

$$\text{for } n = 1,\ a_3 = \frac{\left(aL - \frac{V}{R}\right) a_2}{3K_t} = \frac{\left(aL - \frac{V}{R}\right)^2 a_1}{2K_t \bullet 3K_t} \quad (9)$$

$$\text{for } n = 2;\ a_4 = \frac{\left(aL - \frac{V}{R}\right) a_3}{4K_t} = \frac{\left(aL - \frac{V}{R}\right)}{4K_t} \bullet \frac{\left(aL - \frac{V}{R}\right) a_1}{3K_t \bullet 2K_t} = \frac{\left(aL - \frac{V}{R}\right)^3 a_1}{4K_t \bullet 3K_t \bullet 2K_t} \quad (10)$$

$$\text{for } n = 3;\ a_5 = \frac{\left(aL - \frac{V}{R}\right) a_4}{5K_t} = \frac{\left(aL - \frac{V}{R}\right)}{5K_t \bullet 4K_t \bullet 3K_t \bullet 2K_t} \quad (11)$$

$$\text{for } n;\ a_n - \frac{\left(aL - \frac{V}{R}\right)^{n-1} a_1}{K_t^{\,n-1} n!} \quad (12)$$

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

$$= a_0 + a_1 x + \frac{\left(aL - \frac{V}{R}\right) a_1 x^2}{2!K_t} + \frac{\left(aL - \frac{V}{R}\right) a_2 x^3}{3!K_t^{\,2}} + \frac{\left(aL - \frac{V}{R}\right) a_1 x^4}{4!K_t^{\,3}} + \frac{\left(aL - \frac{V}{R}\right) a_1 x^5}{5!K_t^{\,4}} + \ldots \quad (14)$$

$$C(x) = a_0 + a_1\left[x + \frac{\left(aL - \frac{V}{R}\right) x^2}{2!K_t} + \frac{\left(aL - \frac{V}{R}\right) x^3}{3!K_t^{\,2}} + \frac{\left(aL - \frac{V}{R}\right) x^4}{4!K_t^{\,3}} + \frac{\left(aL - \frac{V}{R}\right) x^5}{5!K_t^{\,4}}\right] \quad (15)$$

$$C(x) = a_0 + a_1\, \ell^{\frac{\left(aL - \frac{V}{R}\right)}{K_t} x} \quad (16)$$

3. Materials and Method

Standard laboratory experiment where performed to monitor the Phosphorus concentration 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 generate variation at different depth producing different migration of phosphorus concentration through pressure flow at lower end of the column, the experimental result are applied to be compared with the theoretical values to determined the validation of the model.

4. Result and Discussion

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

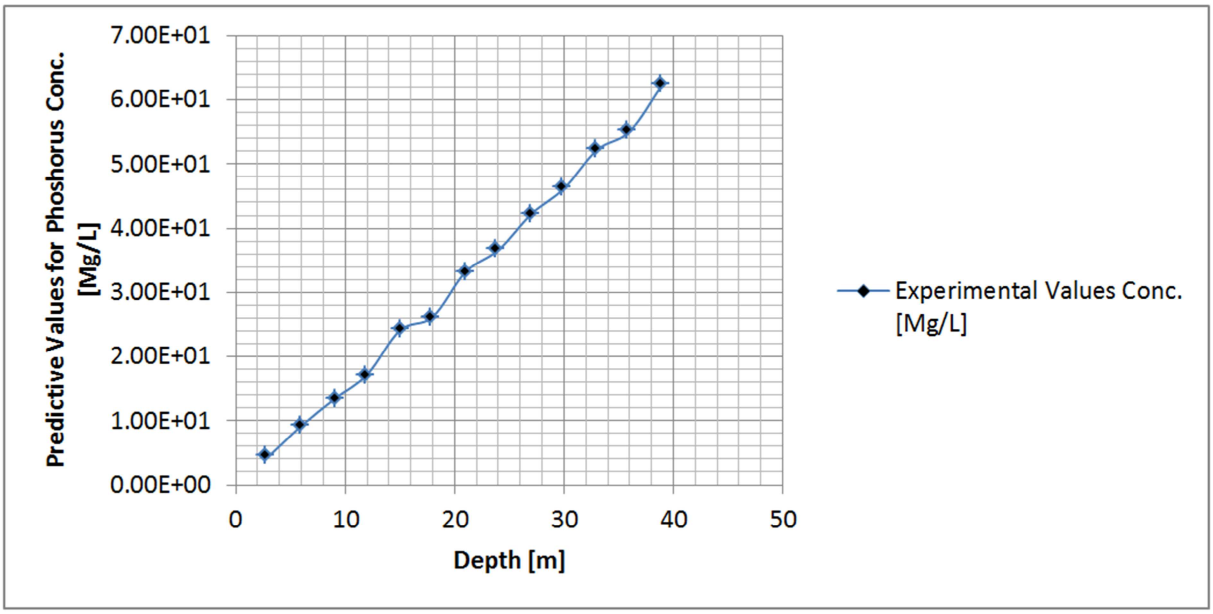

Figure 1. *Concentration of phosphorus at Different Depth.*

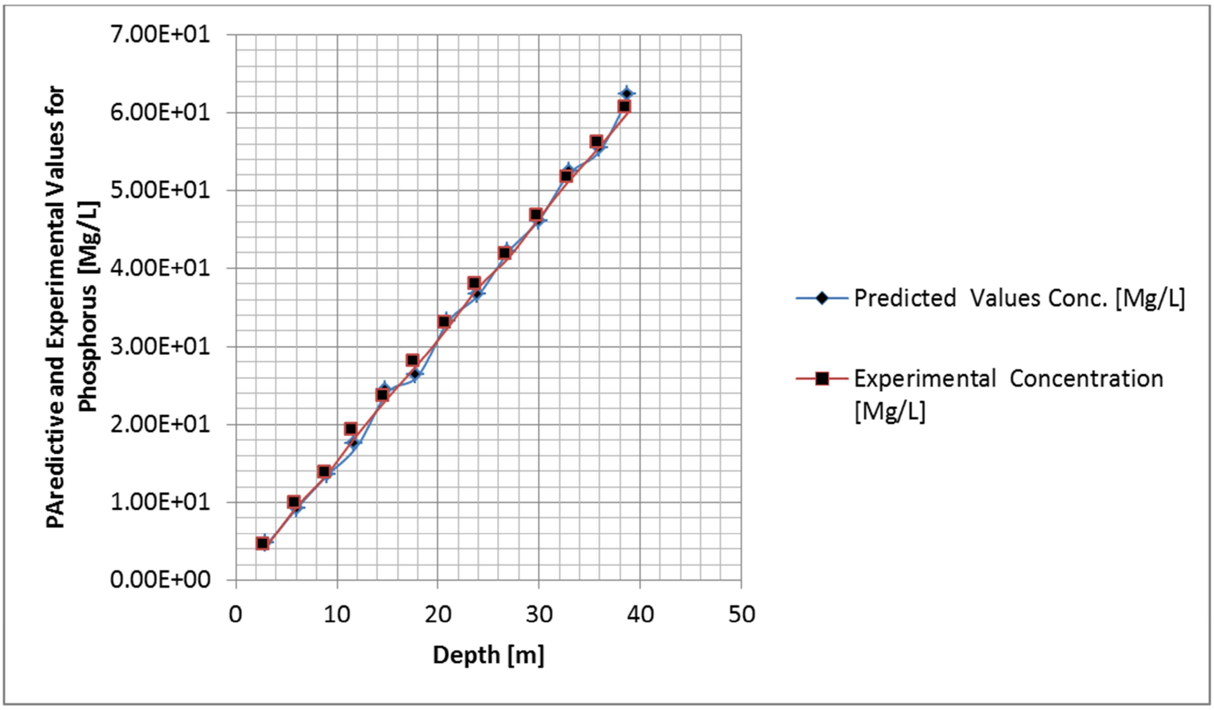

Figure 2. *Predicted and Validate Concentration of phosphorus at Different Depth.*

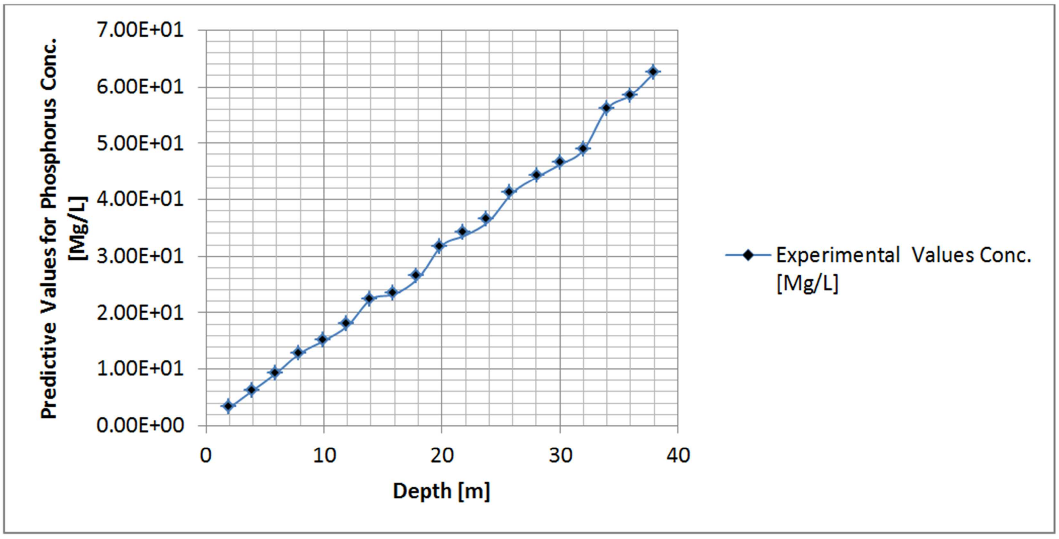

Figure 3. *Concentration of phosphorus at Different Depth.*

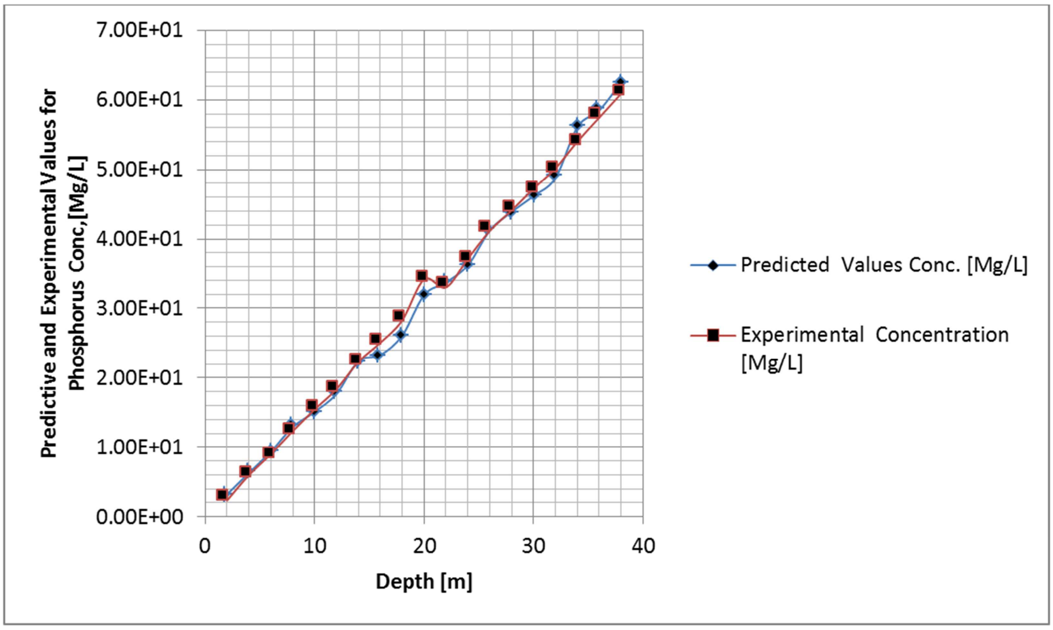

Figure 4. *Predicted and Validate Concentration of phosphorus at Different Depth.*

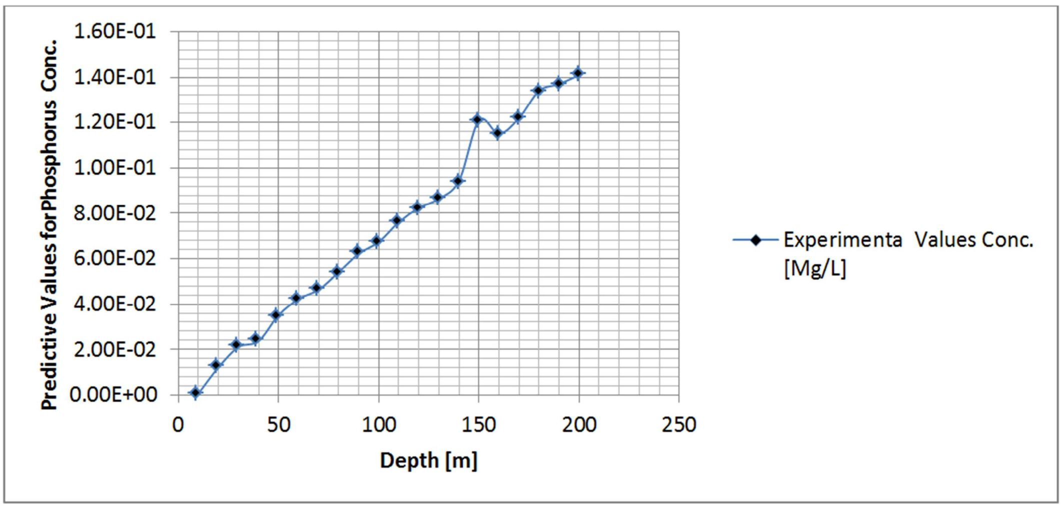

Figure 5. *Concentration of phosphorus at Different Depth.*

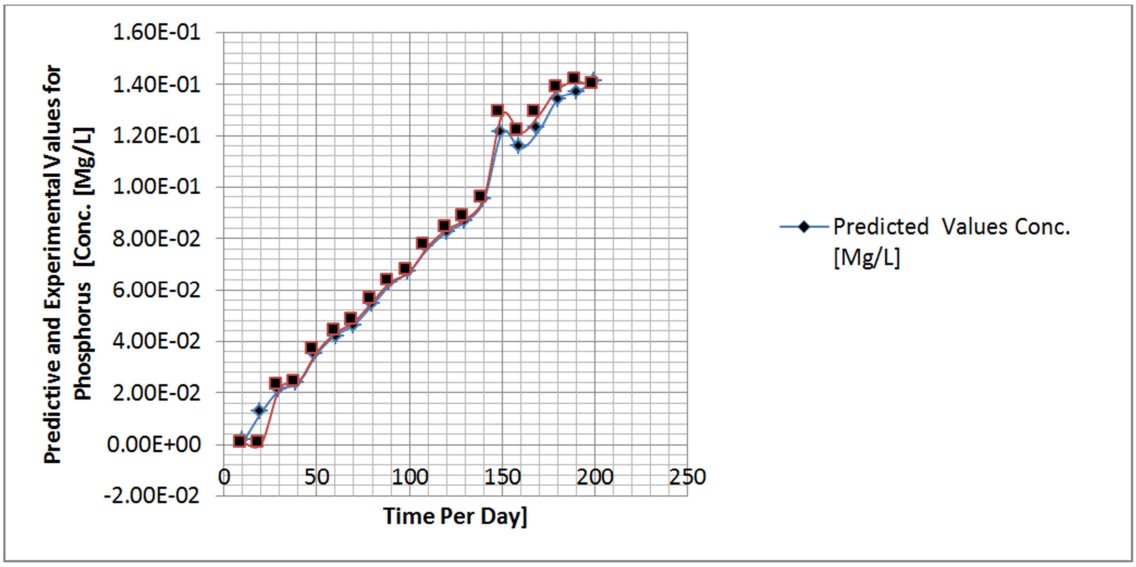

Figure 6. *Predicted and Validate Concentration of phosphorus at Different Depth.*

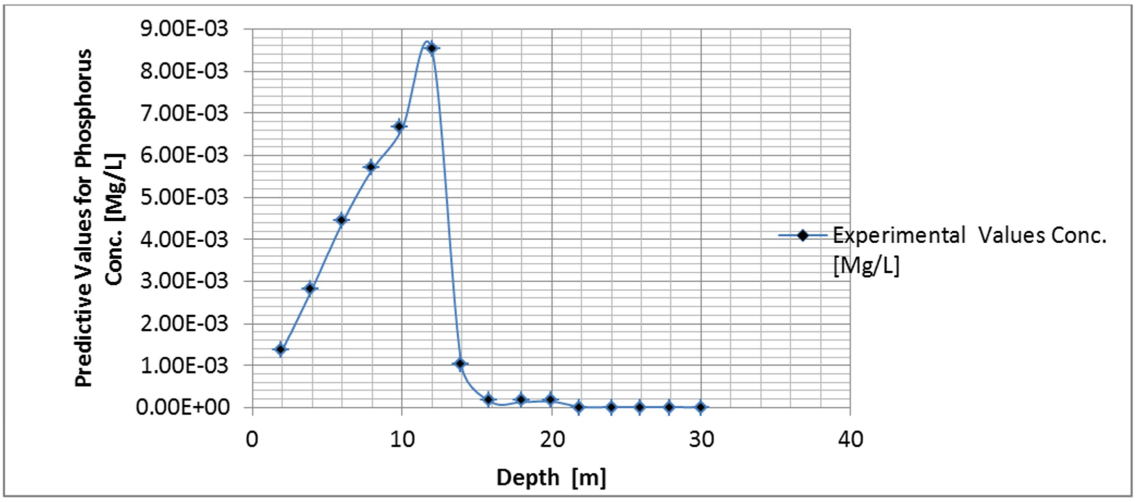

Figure 7. *Concentration of phosphorus at Different Depth.*

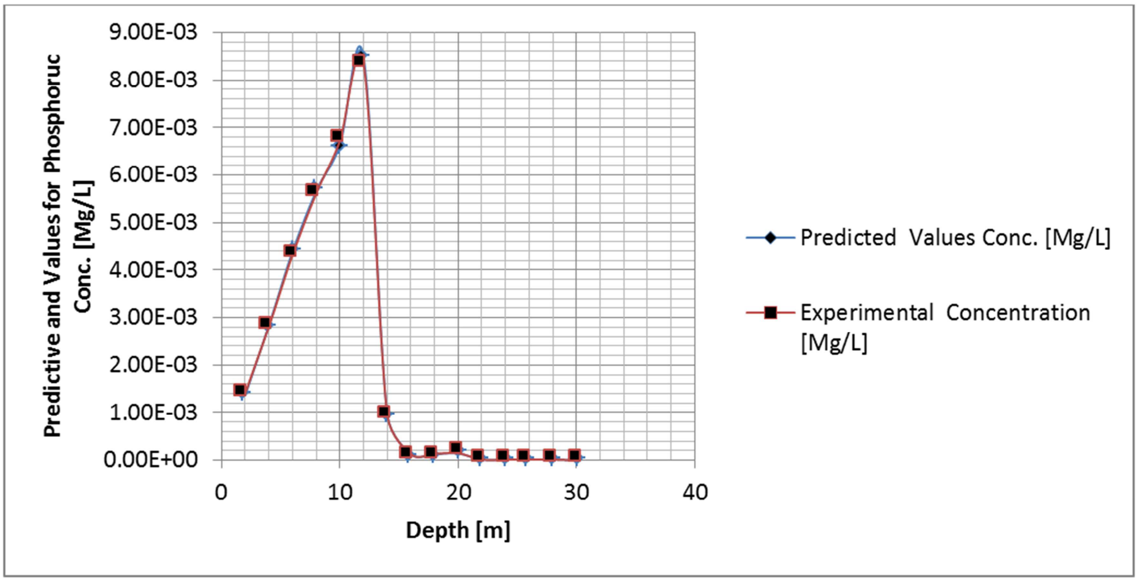

Figure 8. *Predicted and Validate Concentration of phosphorus at Different Depth.*

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

Depth [M]	Experimental Values Conc. [Mg/L]
3	4.44E+00
6	9.22E+00
9	1.34E+01
12	1.72E+01
15	2.41E+01
18	2.62E+01
21	3.32E+01
24	3.66E+01
27	4.22E+01
30	4.62E+01
33	5.22E+01
36	5.51E+01
39	6.24E+01

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

Depth [M]	Predicted Values Conc. [Mg/L]	Experimental Concentration [Mg/L]
3	4.44E+00	4.251
6	9.22E+00	9.407
9	1.34E+01	13.563
12	1.72E+01	18.679
15	2.41E+01	23.375
18	2.62E+01	27.731
21	3.32E+01	32.487
24	3.66E+01	37.543
27	4.22E+01	41.399
30	4.62E+01	46.455
33	5.22E+01	51.311
36	5.51E+01	55.667
39	6.24E+01	60.323

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

Depth [M]	Experimental Values Conc. [Mg/L]
2	3.22E+00
4	6.29E+00
6	9.35E+00
8	1.29E+01
10	1.51E+01
12	1.77E+01
14	2.24E+01
16	2.33E+01
18	2.61E+01
20	3.19E+01
22	3.37E+01
24	3.62E+01
26	4.12E+01
28	4.39E+01
30	4.62E+01
32	4.88E+01
34	5.61E+01
36	5.85E+01
38	6.25E+01

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

Depth [M]	Predicted Values Conc. [Mg/L]	Experimental Concentration [Mg/L]
2	3.22E+00	2.343
4	6.29E+00	5.973
6	9.35E+00	8.983
8	1.29E+01	12.333
10	1.51E+01	15.463
12	1.77E+01	18.383
14	2.24E+01	22.309
16	2.33E+01	25.063
18	2.61E+01	28.283
20	3.19E+01	34.143
22	3.37E+01	33
24	3.62E+01	37.173
26	4.12E+01	41.173
28	4.39E+01	44.133
30	4.62E+01	47.263
32	4.88E+01	50.193
34	5.61E+01	54.023
36	5.85E+01	57.453
38	6.25E+01	60.883

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

Time [T]	Experimental Values Conc. [Mg/L]
10	6.66E-04
20	1.22E-02
30	2.11E-02
40	2.37E-02
50	3.51E-02
60	4.23E-02
70	4.64E-02
80	5.41E-02
90	6.22E-02
100	6.74E-02
110	7.61E-02
120	8.24E-02
130	8.64E-02
140	9.43E-02
150	1.21E-01
160	1.15E-01
170	1.22E-01
180	1.34E-01
190	1.37E-01
200	1.41E-01

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

Time [T]	Predicted Values Conc. [Mg/L]	Experimental Concentration [Mg/L]
10	6.66E-04	6.22E-04
20	1.22E-02	1.31E-04
30	2.11E-02	2.18E-02
40	2.37E-02	2.41E-02
50	3.51E-02	3.58E-02
60	4.23E-02	4.32E-02
70	4.64E-02	4.75E-02
80	5.41E-02	5.53E-02
90	6.22E-02	6.32E-02
100	6.74E-02	6.71E-02
110	7.61E-02	7.69E-02
120	8.24E-02	8.34E-02
130	8.64E-02	8.72E-02
140	9.43E-02	9.53E-02
150	1.21E-01	1.28E-01
160	1.15E-01	1.21E-01
170	1.22E-01	1.28E-01
180	1.34E-01	1.38E-01
190	1.37E-01	1.41E-01
200	1.41E-01	1.39E-01

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

Depth [M]	Experimental Values Conc. [Mg/L]
2	1.37E-03
4	2.83E-03
6	4.39E-03
8	5.66E-03
10	6.63E-03
12	8.49E-03
14	9.66E-04
16	1.29E-04
18	1.32E-04
20	1.46E-04
22	1.60E-05
24	1.73E-05
26	1.79E-05
28	1.88E-05
30	2.34E-06

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

Depth [M]	Predicted Values Conc. [Mg/L]	Experimental Concentration [Mg/L]
2	1.37E-03	1.41E-03
4	2.83E-03	2.81E-03
6	4.39E-03	4.32E-03
8	5.66E-03	5.61E-03
10	6.63E-03	6.72E-03
12	8.49E-03	8.35E-03
14	9.66E-04	9.55E-04
16	1.29E-04	1.29E-04
18	1.32E-04	1.39E-04
20	1.46E-04	1.49E-04
22	1.60E-05	1.69E-05
24	1.73E-05	1.79E-05
26	1.79E-05	1.88E-05
28	1.88E-05	1.94E-05
30	2.34E-06	2.41E-06

The figure under graphical representation evaluates the behaviour of phosphorus deposition in soil and water environment, the substances transport system expresses the rate of concentration at various ways, it has been observed that the transport of phosphorus are observed to be under the influences of higher permeable depositions, therefore the deposition of this type of substance are critically evaluated in the system, such as stratification variation base on the geological setting influences, including deposition of other minerals that may react to hinder their transport, figure one to four express the migration process in exponential phase, these are base on other condition from manmade and natural deposition such as microelement deposition in the study environment, although there may be some minor fluctuation due slight heterogeneous setting, predominance of linear migration were experiences in most locations, these are base on the uniformity through particles size reflecting on the migration process of phosphorus. The behaviour of phosphorus express the rate of concentration as it observed in figure one to six, the transport period [T] were monitored to examine the rate of concentration at different depth, but the homogeneous setting of the formation were expressed through the geological structural deposition influences, the time of concentration were observed in linear phase, the period it take to migrate at different formation. Figure seven and eight experiences fluctuation under physical process from high to low concentration of phosphorus, but the concentration were lower than previous figures, the rate of concentration becoming lower, it can be attributed to change in concentration with respect to depth including other inhibited deposited minerals in the environment, the migration process in various location were compared with the simulated results experienced in fluctuation state. This has expressed the rate of slight heterogeneity in uniformity deposited formation. It was observed to be reflecting directly on the migration process of phosphorus, all the theoretical values from the simulation were compared with experimental data, both parameters developed faviourable fits validating the generated model for the study.

5. Conclusion

The behaviour of the phosphorus has been examined through the developed model for the study; the system developed has evaluated the behaviour of the micronutrient in terms of formation pressure and mineral influences, reflecting on the rate of concentration including their transport process. The study also observes the increase in concentration under the effect from structural uniformity of the formations in the deltaic environment. The developed model monitors the micronutrient predominant exponential deposition in the study location. These are base on the geological setting through the histories as it is reflected on the formation characteristics at various phase of the formation. The developed model expresses some parameters that were found predominant in the study area, it also integrate their relationship in the system to generate the derived governing equation that produces the model. Experts will definitely use these resolved solution as a bench mark to solve other transport issue applying this type of developed concept in the study area.

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