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Modeling and simulation of partial deposition of phosphorous and heavy metal influenced by permeability and void ratio in soil and water in Oyigbo, rivers state of Nigeria

S.N. Eluozo

Subaka Nigeria Limited Port Harcourt, Civil and Environmental Engineering Consultant Department of Research and Development, Rivers State of Nigeria.

*Corresponding author; Subaka Nigeria Limited Port Harcourt, Civil and Environmental Engineering Consultant Department of Research and Development, Rivers State of Nigeria.

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ABSTRACT

Partial depositions of phosphorous study were carried out to monitor the rate of its concentration at various formations, sequentially to ground water aquifers. The study where carried out through the development of mathematical model, the derived equation formulated generated theoretical values, the model values where compared with experimental values, both parameters developed a best fit as presented from the figures, the rate of phosphorous deposition generated the highest concentration at eighteen metres at the period of sixty days, while the lowest were expressed at thirty metres at the period of hundred days. The concentration at the highest degree where found within the fine and coarse sand formation, this is under the influences of high degree of void ratio and permeability in the study location, but at the aquiferious zone were the lowest concentration were recorded, the concentration reduces compared to the deposition within three to eighteen metres were the highest concentration where expressed , the concentration within the aquiferious zone were found to produce a parameters that must be compared with world health organization, if the ground water produced at those depth will be good for human utilization, the model is imperative because partial deposition in the study location can be monitored to determine the growth rate of microbial population migrating to ground water aquifer in the study area.

1. Introduction

Plant litter is a primary nutrient source for saprophytic microbiota in soils, and its quantity and properties strongly influence the formation and humification of soil organic matter (SOM) in terrestrial ecosystems (Swift et al. 1979; Scholes et al. 1997; Kögel-Knabner 2002). Soil microbial biomass represents a significant compartment of terrestrial carbon, and its residues are important parent materials for humus formation (Haider 1992; Kögel-Knabner 2002). Growth of the microorganisms responsible for genesis and cycling of humic substances is influenced by carbon (C) and nitrogen (N) availability in the decomposing plant residues (Balser 2005). During plant residue decomposition, a fraction of the plant C and N is assimilated into the microbial biomass, rendering it largely inaccessible to further biological transformation. The assimilated C and N may remain unavailable to the plant and decomposer community for an appreciable time after microbial death (Jansson and Persson 1982). Little is known, however, about the fate of the C and N in the dead microbial cells. Soil amino sugars are predominantly of microbial origin (Parsons 1981; Stevenson 1982) and are relatively stable over time (Chantigny et al. 1997). The relative representation of different structural classes of amino sugars can be used to differentiate between fungal and bacterial residues in soils (Guggenberger et al. 1999; Glaser et al. 2004).

Understanding the fungal and bacterial contributions to microbial residues can further provide insights into how these organisms govern C and N cycling in soil (Amelung 2001; Simpson et al. 2004). The approach is based on existence of several distinct variations on the molecular structure of amino sugars, with two of them representative of bacteria and one of fungi (Nannipieri et al. 1979; Parsons 1981). Amino sugars are rapidly synthesized during microbial immobilization of inorganic N (McGill et al. 1973), regardless of the type of organic material added to soil (Sowden 1968). Lowe (1973) found that the amino sugar content of forest soils increases with respect to humification. Dai et al. (2002) showed that the level of amino sugar N, as a proportion of total N, remains constant or increases with time in arctic soil microcosms. Amelung et al. (2001) used amino sugars to investigate the fate of microbial residues during beech leaf (Fagus sylvatica L.) litter decomposition; however, their experiment was confined only to pure minerals and plant litters (not real soil). Little is known about the time scale at which amino sugars respond to introduced plant materials in soils

2. Materials and methods

Analytical model were developed, applying mathematical tools, the derived model were applied produced theoretical values that were compared with experimental laboratory analysis. The experimental procedure is column experiment, the soil samples were collected at intervals of three metres each (3m). Phosphorous solute was introduced at the top of the column and effluents from the lower end of the column were collected and analyzed for Phosphorous that generated results from its analysis

2.1. Governing equation

Nomenclature

θ = Void Ratio
K = Permeability
V = Velocity
T = Time
X = Distance
h_{AO} = Concentration deposition phosphorus
Kc = Inhibitors of substrate

$$Kv\frac{\partial h_{AO}}{\partial t} = \theta\frac{\partial h_{AO}}{\partial x} + Kc \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

$$h_{AO} = TZ$$

$$\frac{\partial h_{AO}}{\partial t} = T^1 Z \qquad \ldots\ldots\ldots\ldots \qquad (2)$$

$$\frac{\partial h_{AO}}{\partial X} = TZ^1 \qquad \ldots\ldots\ldots\ldots \qquad (3)$$

$$Kv\frac{T^1 Z}{TZ} = \theta\frac{T^1 Z}{TZ} + Kc = -\lambda^2 \qquad \ldots\ldots\ldots\ldots \qquad (4)$$

$$Kv\frac{T^1}{T} = \theta\frac{Z^1}{Z} + Kc = -\lambda^2 \qquad \ldots\ldots\ldots\ldots \qquad (5)$$

$$Kv\frac{T^1}{T} = -\lambda^2 \qquad \ldots\ldots\ldots\ldots \qquad (6)$$

$$\theta\frac{Z^1}{Z} + Kc = -\lambda^2 \qquad \ldots\ldots\ldots\ldots \qquad (7)$$

From (7) $T^1 + \frac{\lambda^2 T}{Kv} = 0$

$$Z = A\,Cos\frac{\lambda^2}{\sqrt{Kv}}t \quad + B\,Sin\frac{\lambda^2}{\sqrt{Kv}}t \qquad \ldots\ldots\ldots\ldots \qquad (8)$$

From (6) $\theta\frac{Z^1}{Z} + Kc - \lambda^2$ $\qquad \ldots\ldots\ldots\ldots \qquad (9)$

$$\frac{Z^1}{Z} = \frac{-\lambda^2}{\theta Kc} \qquad \ldots\ldots\ldots\ldots \qquad (10)$$

By direct integration

$$LnT = \frac{\lambda^2}{\theta Kc}Z \qquad \ldots\ldots\ldots\ldots \qquad (11)$$

$$Z = D\ell^{\frac{-\lambda^2}{\theta Kc}Z} \qquad \ldots\ldots\ldots\ldots \qquad (12)$$

Combining (8) and (9) yields

$$h_{AO}\left(Z,t\right) = \left[A\,Cos\frac{\lambda}{\sqrt{Kv}}t + B\,Sin\frac{\lambda}{\sqrt{\theta Kc}}Z\right]D\ell^{\frac{-\lambda^2}{\theta Kc}Z} \qquad \ldots\ldots \qquad (13)$$

$$At = 0 \;\; h_{AO}(o) = h_{AO}$$

$$h_{AO} = A\,Cos\frac{\lambda}{\sqrt{Kv}}t + B\,Sin\frac{\lambda}{\sqrt{\theta Kc}}Z$$

$$\left.\frac{\partial h_{AO}}{\partial t}\right|_{t\ =\ 0,B} = 0 \qquad \ldots\ldots\ldots\ldots\ldots \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (14)$$

$$From\ (13)\ \frac{\partial h_{AO}}{\partial t} = \left[-A\frac{\lambda}{\sqrt{Kv}}\ Sin\frac{\lambda}{\sqrt{Kv}}t + B\frac{\lambda}{\sqrt{Kv}}\ Cos\frac{\lambda}{\sqrt{Kv}}t\right]D\ell^{\frac{-\lambda^2}{\theta Kc}Z} \ \ldots\ldots \qquad (15)$$

$$At\ t = 0$$

$$0 = B\frac{\lambda}{\sqrt{Kv}}D\ell^{\frac{-\lambda^2}{\theta Kc}Z} \Rightarrow B = 0\,D \neq 0 \qquad \ldots\ldots\ldots\ldots\ldots \qquad \ldots\ldots\ldots\ldots\ldots \qquad (16)$$

$$h_{AO} = \left[A\,Cos\frac{\lambda}{\sqrt{Kv}}\right]D\ell^{\frac{-\lambda^2}{\theta Kc}Z} \qquad \ldots\ldots\ldots\ldots\ldots \qquad \ldots\ldots\ldots\ldots\ldots \qquad (17)$$

$$h_{AO} = AD\,Cos\frac{\lambda}{\sqrt{Kv}}t\ \ell^{\frac{-\lambda^2}{\theta Kc}Z} \qquad \ldots\ldots\ldots\ldots\ldots \qquad \ldots\ldots\ldots\ldots\ldots \qquad (18)$$

$$\frac{\partial h_{AO}}{\partial t} = \frac{AD\lambda}{\sqrt{Kv}}\ Sin\frac{\lambda}{\sqrt{Kv}}t\ \ell^{\frac{-\lambda^2}{\theta Kc}Z} \qquad \ldots\ldots\ldots\ldots\ldots \qquad \ldots\ldots\ldots\ldots\ldots \qquad (19)$$

$$At\ \ t = \frac{\partial h_{AO}}{\partial t} = 0$$

$$0 = \frac{AD\lambda}{\sqrt{Kv}}\ Sin\frac{\lambda d}{\sqrt{Kv}} = n\pi = \frac{\lambda\partial}{\sqrt{Kv}},\ n = 0,1,2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (20)$$

$$\Rightarrow \lambda = n\pi\frac{\sqrt{Kv}}{d} \qquad \ldots\ldots\ldots\ldots\ldots \qquad \ldots\ldots\ldots\ldots\ldots \qquad (21)$$

So that we have

$$h_{AO}\ (Z,t) = AD\,Cos\ n\pi\frac{\sqrt{Kv}}{d\sqrt{Kv}}t\ \ell\ \frac{-n^2\pi^2Kv}{d^2\theta Kc}Z \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (22)$$

$$AD\,Cos\frac{n\pi}{d}t\ \ell\ \frac{-n^2\pi^2Kv}{d^2\theta Kc}Z \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (23)$$

Hence $AD = h_{AO}$

$$\boxed{h_{AO} = \ (Z,t) = h_{AO}\ \ell\ \frac{-n^2\pi^2Kv}{d^2\theta Kc}Z\ \ Cos\frac{n\pi}{d}t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (24)$$

3. Results and discussion

Results from theoretical values with experimental values on deposition of phosphorous at various formations are presented in tables and figures bellow

Table 1
Comparison of theoretical and experimental values of partial deposition of phosphorous at various depths.

Depth	Theoretical values	Experimental values
3	20.71	22.22
6	39.74	39.66
9	56.51	58.57
12	69.55	67.44
15	78.66	78.55
18	81.97	82.95
21	81.14	80.45
24	71.21	72.34
27	57.75	56.88
30	35.19	35.21

Table 2
Comparison of theoretical and experimental values of partial deposition of phosphorous at various Times.

Time per Day	Theoretical values	Experimental values
10	20.71	22.22
20	39.74	39.66
30	56.51	58.57
40	69.55	67.44
50	78.66	78.55
60	81.97	82.95
70	81.14	80.45
80	71.21	72.34
90	57.75	56.88
100	35.19	35.21

Table 3
Comparison of theoretical and experimental values of partial deposition of phosphorous at various depths.

Depth	Theoretical values	Experimental values
3	9.78	9.45
6	17.98	17.44
9	26.97	27.12
12	33.2	32.21
15	37.55	37.44
18	39.13	41.12
21	38.73	37.88
24	33.99	32.88
27	27.57	26.87
30	16.79	16.74

Table 4

Comparison of theoretical and experimental values of partial deposition of phosphorous at various times.

Time per Day	Theoretical values	Experimental values
10	9.78	9.45
20	17.98	17.44
30	26.97	27.12
40	33.2	32.21
50	37.55	37.44
60	39.13	41.12
70	38.73	37.88
80	33.99	32.88
90	27.57	26.87
100	16.79	16.74

Table 5
Comparison of theoretical and experimental values of partial deposition of phosphorous at various depths.

Depth	Theoretical values	Experimental values
3	16.31	16.22
6	31.62	32.45
9	44.97	45.88
12	55.34	55.22
15	62.59	61.78
18	65.33	66.24
21	64.57	63.56
24	56.66	57.12
27	45.95	46.2
30	28.1	28.11

Table 6
Comparison of theoretical and experimental values of partial deposition of phosphorous at various times.

Time per Day	Theoretical values	Experimental values
10	16.31	16.22
20	31.62	32.45
30	44.97	45.88
40	55.34	55.22
50	62.59	61.78
60	65.33	66.24
70	64.57	63.56
80	56.66	57.12
90	45.95	46.2
100	28.1	28.11

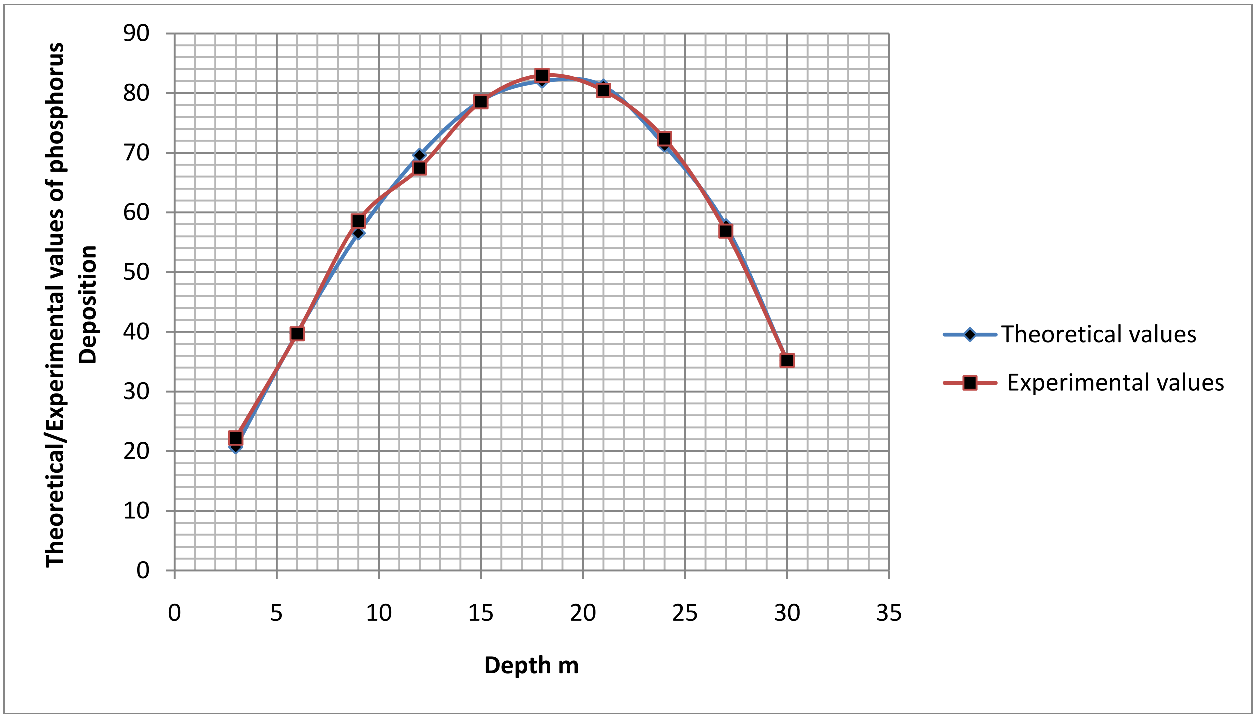

Fig. 1. Comparison of theoretical and experimental values of partial deposition of phosphorous at various depths.

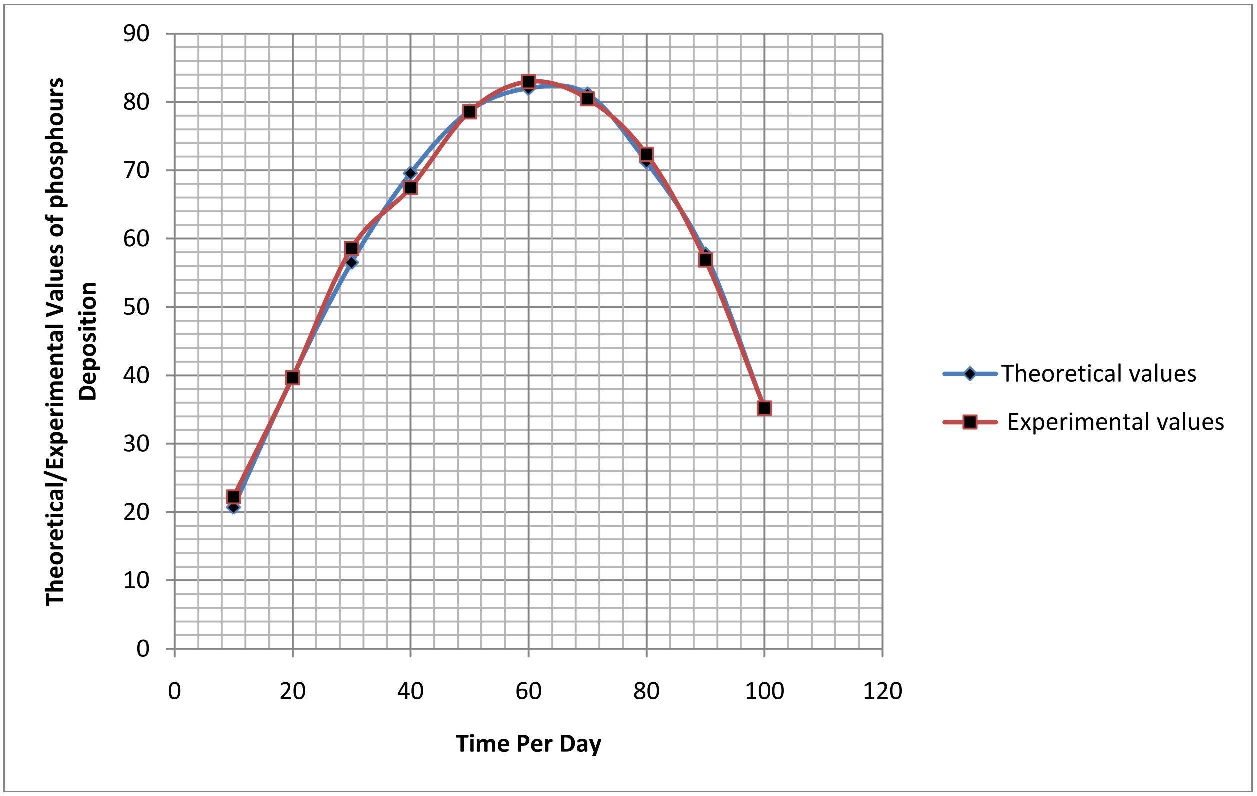

Fig. 2. Comparison of theoretical and experimental values of partial deposition of phosphorous at various times.

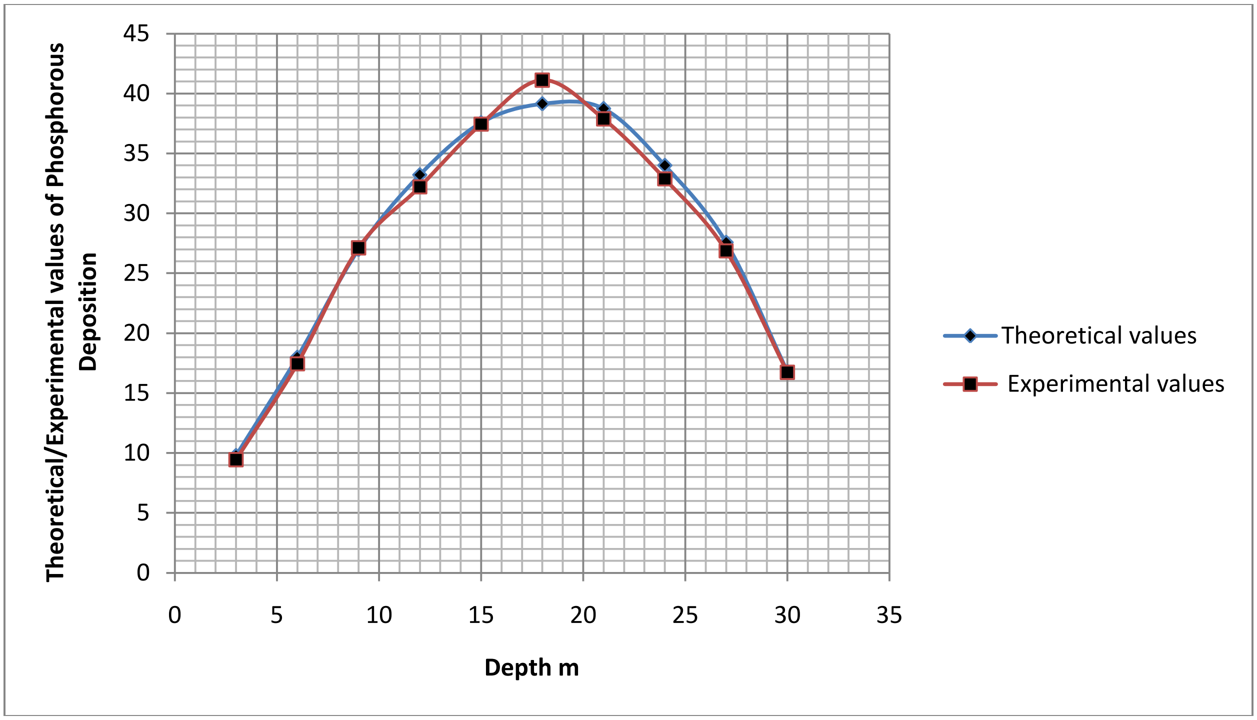

Fig. 3. Comparison of theoretical and experimental values of partial deposition of phosphorous at various depths.

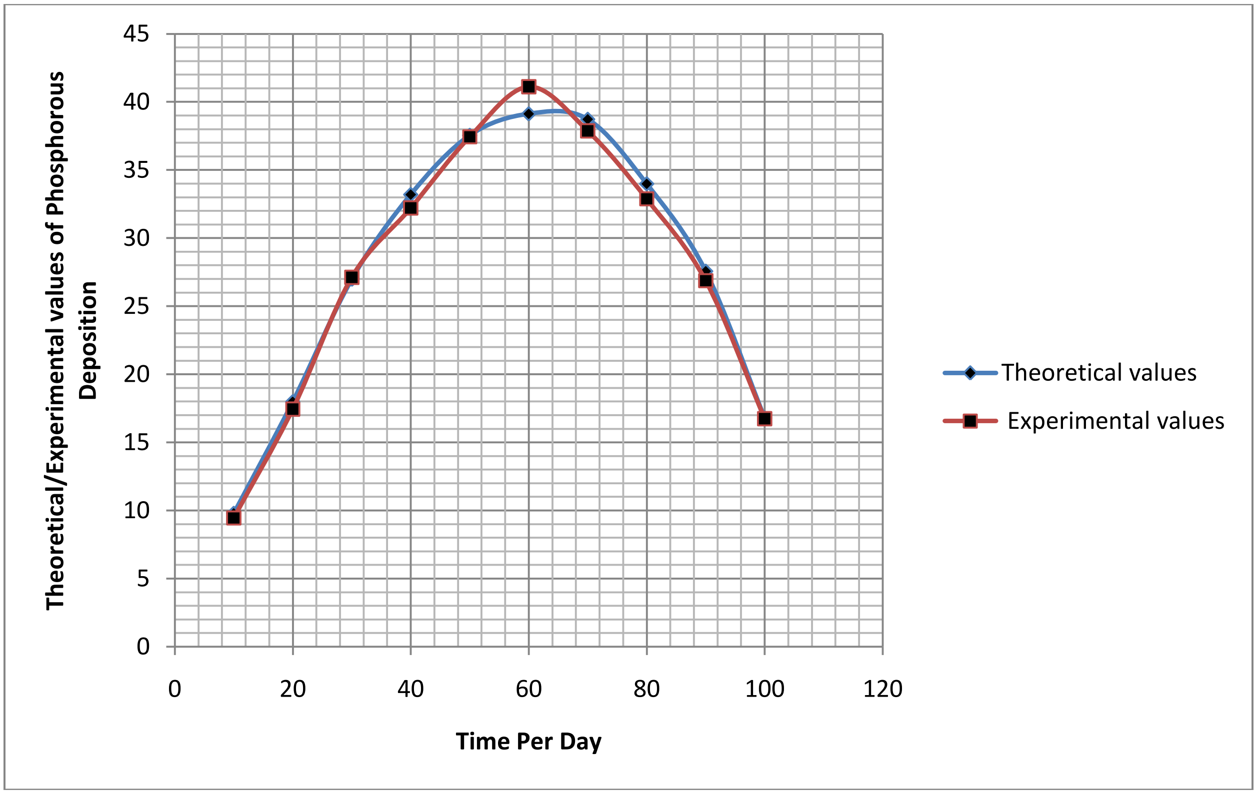

Fig. 4. Comparison of theoretical and experimental values of partial deposition of phosphorous at various times.

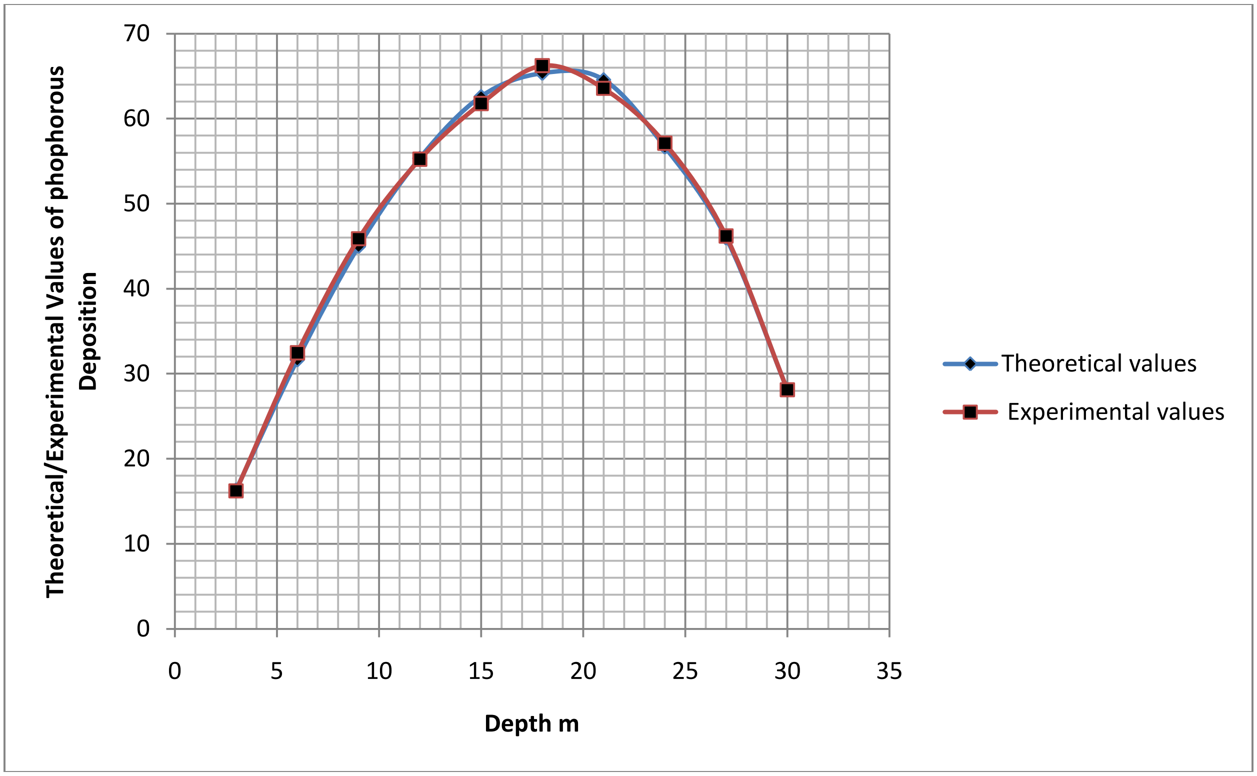

Fig. 5. Comparison of theoretical and experimental values of partial deposition of phosphorous at various depths.

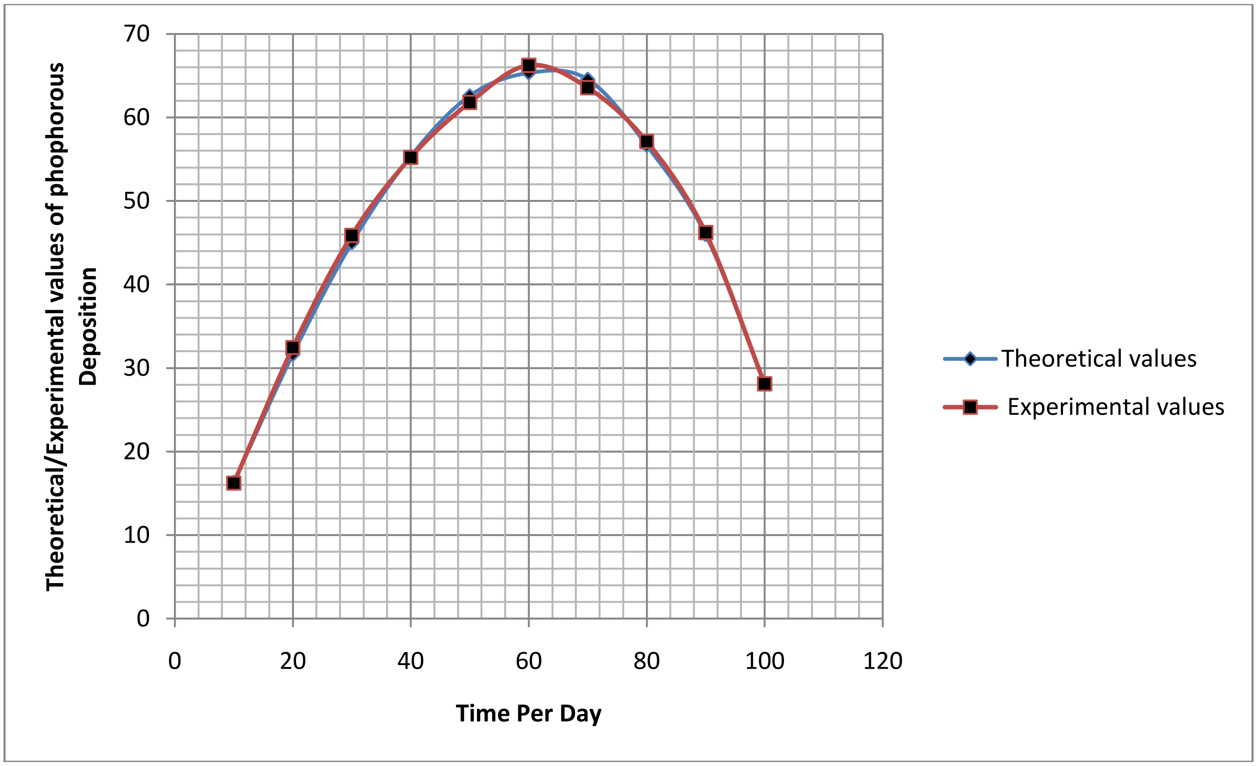

Fig. 6. Comparison of theoretical and experimental values of partial deposition of phosphorous at various times.

Figure one to five shows that the deposition of phosphorous gradually increase from three metres at the period of ten days to where the optimum values where recorded at eighteen metres at sixty days, sudden decrease where observed from twenty four metres at seventy days to thirty metres at hundred days, the developed model generated theoretical values that were generated from the derived equation, the theoretical values where also compared with experimental values, both parameters developed a best fit, these condition shows that the model can be applied to monitor partial deposition of phosphorous in soil and water environment, partial depositions of the microelements are studied to monitor the rate of deposition at every formation in the study area, many researchers has only study the deposition of the microelements on some particular soil, but this study are carried out to monitor the rate of deposition of phosphorous sequentially to ground water aquifers, the rate of deposition depend on natural origin or man made activities, Moreso the rate of phosphorous also depend on the permeability of the formation, the rate of micro-pole of the soil also influence the deposition of this microelements at various soil formations, the rate of deposition of the microelements shows that formation at the study location were as permeable as presented in the figures, the deposition of phosphorous from the figure presented developed the highest concentration at eighteen metres at period of sixty days, and the lowest at thirty metres at the period of hundred, variation of permeability generated the results within the stratum of coarse and fine sand formation, this implies that at the formation within three to twelve metres at the period of ten to forty days, there is a trace of some high concentration of inhibitors at those formations, but from other formation at later periods the inhibitor reduces with respect to time and distance, this condition generated fast migration of the substrate ,developing the highest concentration at eighteen metres at the period of sixty days within coarse and fine sand formation at the study area. Finally the formation where the aquiferious zone are deposited were found to decrease, this condition can be attributed to partial deposition of the microelements, including the rate of dispersion, the rate hydrostatic pressure may have reduce the concentration, but it should be monitored if the degree of concentration at ground water aquifer are within the stipulated standard for human utilization.

4. Conclusion

Partial deposition of phosphorous in soil and water environment has been expresses at various condition, the developed model generated theoretical values at different time and distance, the resulted from theoretical values where compared with experimental values, and both parameters developed a best fit, the developed model expresses the rate of phosphorous deposition at various depth, high concentration were recorded at eighteen meters, while the lowest concentration where recorded at thirty metres, the rate of concentration of the microelements has been expressed from the generated theoretical values, the influence that resulted to high deposition of the microelements at eighteen metres has been expresses, permeability and void ratio variation at various soil formation where found to play a major role on high concentration of the microelements at the stratum. The model can be applied to monitor the rate of phosphorous deposition in the study area.

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