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Original article

Modeling and simulation to predict partial deposition of ammonia and specific growth rate of bacterial in homogeneous formation in Obio/Akpor, rivers state of Nigeria

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A B S T R A C T

Specific growth rate of bacteria has been expressed through characteristics influence deposition at various stratums to aquiferous zone. The growth rates of bacteria are under the influence of the substrate utilization that contaminates groundwater aquifers in various formations. Derived mathematical equations generated theoretical values that expressed the rate of exponential phase of ammonia deposition and bacteria growth rate in homogenous formation. Slight fluctuations were experienced in between the aquiferous zones under the influence of variation from degree of porosity and permeability of the stratum. Experimental values were compared with the theoretical values; both parameters produced a best fit. These expressed the application of the derived model that determines partial deposition of ammonia and bacteria growth rate in homogenous formation. The study is imperative because the model expressed partial depositions of ammonia that determine the growth rate of bacteria at various formations to groundwater aquifers in the study area.

1. Introduction

Ammonia is used in fertilizer and animal feed production and in the manufacture of fibers, plastics, explosives, paper, and rubber. It is used as a coolant, in metal processing, and as a starting product for many nitrogen-containing compounds (*3*). Ammonia and ammonium salts are used in cleansing agents and as food additives (*1,4*), and ammonium chloride is used as a diuretic [Source: *Hazardous Substances Data Bank: Ammonium chloride.* Bethesda, MD, National Library of Medicine, 1990, WHO 1996)

Microelements are nutritional components that occur and function in many locations and on many levels of organism. They are present in the organism at very low concentrations and are an indispensable component in numerous enzymatic, catalytic, regulating and activating processes, usually as activators and co-factors. Microelements enter the organism through the feed; in developing foetuses they enter through the placenta. Concentration of microelements in blood of supplemented mothers correlates positively with concentrations in calf blood. An important source of microelements for a newborn calf is the colostrums (Abdelrahman and Kincaid 1993; Lacetera 1996; Underwood and Suttle 1999; Pavlata et al. 2003). Microelements also affect the quality and composition of the colostrums and milk and affect the health of the udder. For example, the colostrums and milk of selenium-supplemented cows has a higher concentration of selenium and contains a higher concentration of immunoglobulin's; cows supplied with selenium have lower incidence of mastitis (Hogan et al. 1993; Knowles et al. 1999; Pavlata et al. 2004a); supplementation of zinc to dairy cows decreases the number of somatic cells in milk (Pechová et al. 2006), and copper affects the ability of neutrophils to kill phagocytosed bacteria and decreases susceptibility of the udder to infection (Scaletti et al. 2003). Microelement deficiencies in dairy and beef cattle in the Czech Republic are frequent (Pavlata et al. 2005a; Slavík et al. 2006; Podhorský et al. 2007). Ruminant nutrition routinely uses several methods and forms to supplement microelements. A slightly problematic period for ensuring adequate supplementation of microelements to dairy cows is the dry period, when only a small amount of seeds is usually fed and microelements are thus difficult to add to the feed. Application forms include supplementation by adding minerals to the feed, mineral licks, and/or single/repeated injection of individual microelements, or combinations of the above. Other methods of supplementation include boluses, projectiles or pills (depending on the shape of administration form), containing a precisely defined amount of microelements combined with a carrier or auxiliary substance. Another method of supplementation of microelements consists in long-acting injections (Lee et al. 1999; Pavlata 2004a; Kinal et al. 2004; Pechová et al. 2006; Mulligan et al. 2006; Chládek and Zapletal 2007).

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). Ammonia solute was introduced at the top of the column and effluents from the lower end of the column were collected and analyzed for Ammonia that generated results from its analysis

2.1. Governing Equation

$$\frac{\mu_o}{\mu_n}\frac{\partial K_O}{\partial t} = \frac{\partial K_O}{\partial x}Kv + Kc \qquad \text{..} \qquad (1)$$

Nomenclature

θ	=	Void Ratio
K	=	Permeability
V	=	Velocity
T	=	Time
X	=	Distance

h_{AO} = Concentration deposition phosphorus

Kc = Inhibitors of substrate

$$K_O = XT$$

$$\frac{\partial K_O}{\partial t} = XT^1 \quad \text{....................................} \quad (2)$$

$$\frac{\partial K_O}{\partial X} = TX^1 \quad \text{....................................} \quad (3)$$

$$\frac{\mu_o}{\mu_n}\frac{T^1 X}{TX} = \frac{TX^1}{TX}\; Kv + Kc = -\lambda^2 \quad \text{....................................} \quad (4)$$

$$\frac{\mu_o}{\mu_n}\frac{T^1 X}{TX} = \frac{X^1}{X}\; Kv + Kc = -\lambda^2 \quad \text{....................................} \quad (5)$$

$$\frac{\mu_o}{\mu_n}\frac{T^1}{T} = -\lambda^2 \quad \text{....................................} \quad (6)$$

$$\frac{X^1}{X} Kv + Kc = -\lambda^2 \quad \text{....................................} \quad (7)$$

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

$$X = ACos\frac{\lambda}{\sqrt{\frac{\mu_O}{\mu_N}}}t \quad + B\,Sin\frac{\lambda}{\sqrt{\frac{\mu_O}{\mu_N}}}t \quad \text{................................} \quad (8)$$

From (6) $\frac{Z^1}{Z}Kv + Kc - \lambda^2$ .... (9)

$$\frac{Z^1}{Z} = \frac{-\lambda^2}{KvKc} \quad \text{....................................} \quad (10)$$

By direct integration

$$LnT = \frac{\lambda^2}{KvKc}Z \quad \text{....................................} \quad (11)$$

$$Z = D\ell^{\frac{-\lambda^2}{KvKc}Z} \quad \text{....................................} \quad (12)$$

Combining (8) and (9) yields

$$Ko\left(Z,t\right) = \left[ACos\frac{\lambda}{\sqrt{\frac{\mu_o}{\mu_n}}}t + BSin\frac{\lambda}{\sqrt{KvKc}}Z\right]D\ell^{\frac{-\lambda^2}{KvKc}Z} \quad .... \quad (13)$$

$$At = 0 \ \ Ko\,(o) = Ko$$

$$Ko = ACos\frac{\lambda}{\sqrt{\frac{\mu_o}{\mu_n}}}t + BSin\frac{\lambda}{\sqrt{KvKo}}Z$$

$$\frac{\partial Ko}{\partial t}\Bigg|_{t\,=\,0,B} = 0 \quad .... \quad .... \quad (14)$$

$$From\ (13)\ \frac{\partial Ko}{\partial t} = \left[-A\frac{\lambda}{\sqrt{\frac{\mu_o}{\mu_n}}}\ Sin\frac{\lambda}{\sqrt{\frac{\mu_o}{\mu_n}}}t + B\frac{\lambda}{\sqrt{\frac{\mu_o}{\mu_n}}}\ Cos\frac{\lambda}{\sqrt{\frac{\mu_o}{\mu_n}}}t\right]D\ell^{\frac{-\lambda^2}{KvKc}Z} \quad .... \quad (15)$$

$$At\ t = 0$$

$$0 = B\frac{\lambda}{\sqrt{KvKo}}D\ell^{\frac{-\lambda^2}{KvKc}Z} \Rightarrow B = 0\,D \neq 0 \quad .... \quad .... \quad (16)$$

$$Ko = \left[ACos\frac{\lambda}{\sqrt{\frac{\mu_o}{\mu_n}}}\right]D\ell^{\frac{-\lambda^2}{KvKc}Z} \quad .... \quad .... \quad (17)$$

$$Ko = AD\,Cos\frac{\lambda}{\sqrt{\frac{\mu_o}{\mu_n}}}t\ \ell^{\frac{-\lambda^2}{KvKc}Z} \quad .... \quad (18)$$

$$\frac{\partial Ko}{\partial t} = AD\frac{-\lambda}{\sqrt{\frac{\mu_o}{\mu_n}}}\ Sin\frac{\lambda}{\sqrt{\frac{\mu_o}{\mu_n}}}t\ \ell^{\frac{-\lambda^2}{KvKc}Z} \quad .... \quad (19)$$

$$At\ \ t = \frac{\partial Ko}{\partial t} = 0$$

$$0 = \frac{AD\lambda}{\sqrt{\frac{\mu_o}{\mu_n}}} Sin \frac{\lambda d}{\sqrt{\frac{\mu_o}{\mu_n}}} = n\pi = \frac{\lambda d}{\sqrt{\frac{\mu_o}{\mu_n}}}, n=0,1,2 \quad \ldots\ldots\ldots\ldots \quad (20)$$

$$\Rightarrow \lambda = n\pi \frac{\sqrt{\frac{\mu_o}{\mu_n}}}{d} \quad \ldots\ldots\ldots \quad \ldots\ldots\ldots \quad (21)$$

So that we have

$$Ko\left(Z,t\right) = AD\, Cos\; n\pi \frac{\sqrt{\frac{\mu_o}{\mu_n}}}{d\sqrt{\frac{\mu_o}{\mu_n}}} t\; \ell\; \frac{-n^2\pi^2 \frac{\mu_o}{\mu_n}}{d^2 KvKc} Z \quad \ldots\ldots\ldots\ldots \quad (22)$$

$$AD\, Cos \frac{n\pi}{d} t\; \ell\; \frac{-n^2\pi^2 \frac{\mu_o}{\mu_n}}{d^2 KvKc} Z \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

Hence $AD = Ko$

$$\boxed{Ko = \left(Z,t\right) = Ko\; \ell\; \frac{-n^2\pi^2 \frac{\mu_o}{\mu_n}}{d^2 KvKc} Z \;\; Cos \frac{n\pi}{d} t} \quad \ldots\ldots\ldots\ldots \quad (24)$$

3. Results and discussion

Modeling and simulation to predict partial deposition of ammonia and specific growth rate of bacterial in homogeneous formation in are presented in tables and figures bellow.

Table 1

Comparison of theoretical and experimental values of partial deposition of ammonia at various depths.

Depth M	Theoretical values	Experimental values
3	1.43E-06	1.48E-06
6	2.86E-06	2.77E-06
9	4.29E-06	4.44E-06
12	5.71E-06	5.67E-06
15	6.35E-06	6.44E-06
18	7.62E-06	7.88E-06
21	8.89E-06	8.56E-06
24	1.02E-05	1.11E-05
27	1.14E-05	1.18E-05
30	1.27E-05	1.32E-05

Table 2
Comparison of theoretical and experimental values of partial deposition of ammonia at various times.

Time per Day	Theoretical values	Experimental values
10	1.43E-06	1.48E-06
20	2.86E-06	2.77E-06
30	4.29E-06	4.44E-06
40	5.71E-06	5.67E-06
50	6.35E-06	6.44E-06
60	7.62E-06	7.88E-06
70	8.89E-06	8.56E-06
80	1.02E-05	1.11E-05
90	1.14E-05	1.18E-05
100	1.27E-05	1.32E-05

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

Depth M	Theoretical values	Experimental values
3	2.84E-06	2.77E-06
6	1.70E-05	1.66E-05
9	2.55E-05	2.44E-05
12	3.40E-05	3.45E-05
15	4.26E-05	4.45E-05
18	5.11E-05	5.55E-05
21	5.96E-05	6.11E-05
24	6.81E-05	6.55E-05
27	7.67E-05	7.44E-05
30	8.52E-05	8.44E-05

Table 4
Comparison of theoretical and experimental values of partial deposition of ammonia at various times.

Time per Day	Theoretical values	Experimental values
10	2.84E-06	2.77E-06
20	1.70E-05	1.66E-05
30	2.55E-05	2.44E-05
40	3.40E-05	3.45E-05
50	4.26E-05	4.45E-05
60	5.11E-05	5.55E-05
70	5.96E-05	6.11E-05
80	6.81E-05	6.55E-05
90	7.67E-05	7.44E-05
100	8.52E-05	8.44E-05

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

Depth M	Theoretical values	Experimental values
3	5.96E-08	5.88E-07
6	2.38E-07	2.45E-07
9	5.11E-07	5.33E-07
12	9.53E-07	9.44E-07
15	1.59E-06	1.64E-06
18	2.14E-06	2.23E-06
21	2.90E-06	2.88E-06
24	3.81E-06	3.77E-06
27	4.80E-06	4.77E-06
30	5.96E-06	5.88E-06

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

Time per Day	Theoretical values	Experimental values
10	5.96E-08	5.88E-07
20	2.38E-07	2.45E-07
30	5.11E-07	5.33E-07
40	9.53E-07	9.44E-07
50	1.59E-06	1.64E-06
60	2.14E-06	2.23E-06
70	2.90E-06	2.88E-06
80	3.81E-06	3.77E-06
90	4.80E-06	4.77E-06
100	5.96E-06	5.88E-06

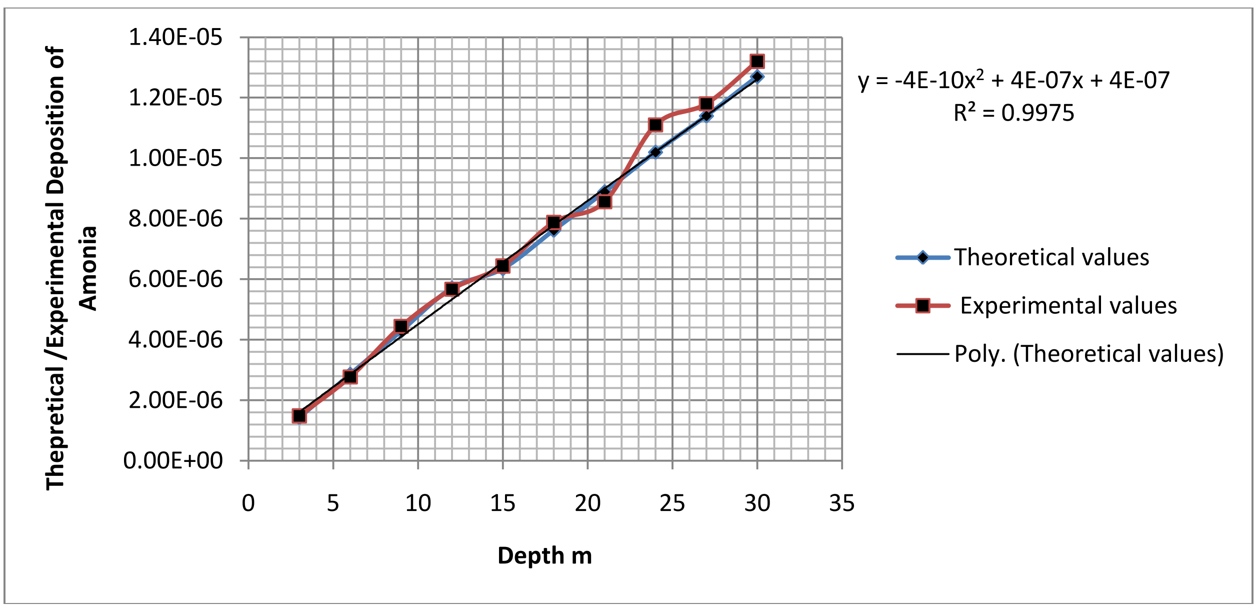

Fig. 1. Comparison of theoretical and experimental values of partial deposition of ammonia at various depths.

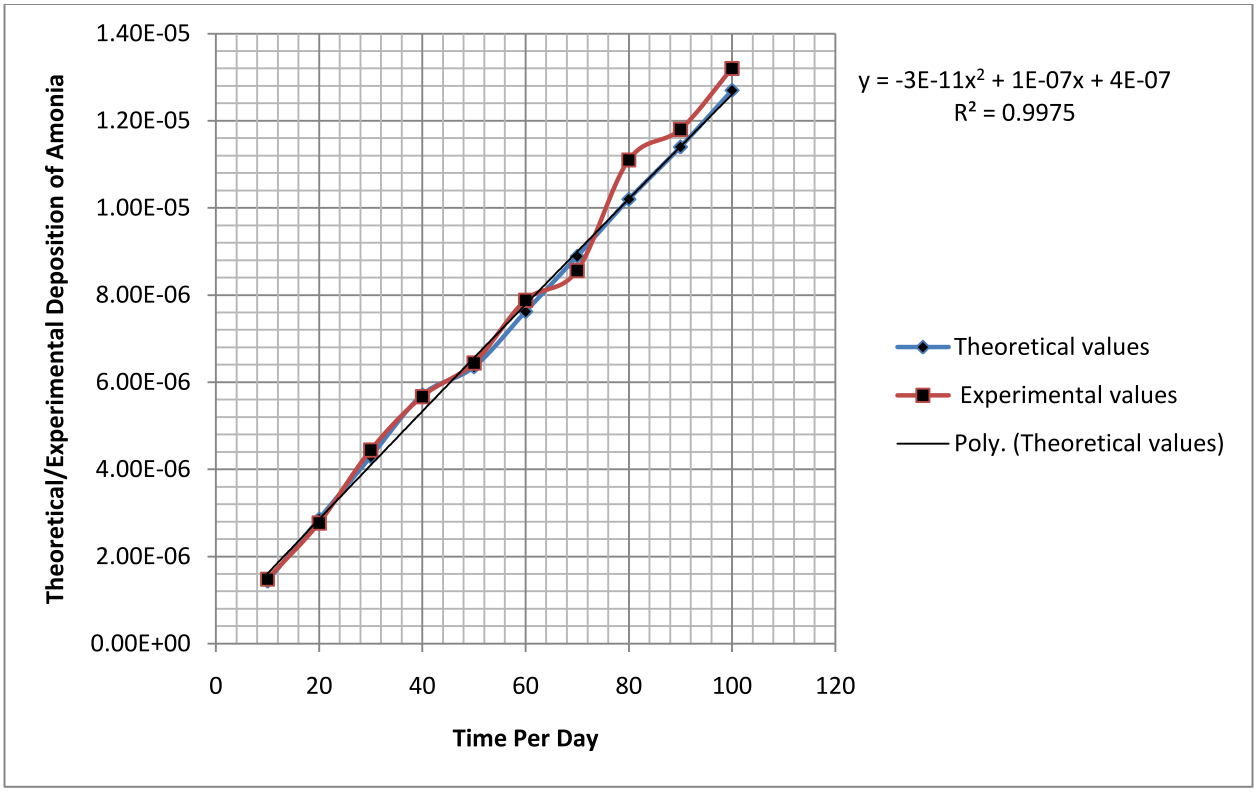

Fig. 2. Comparison of theoretical and experimental values of partial deposition of ammonia at various times.

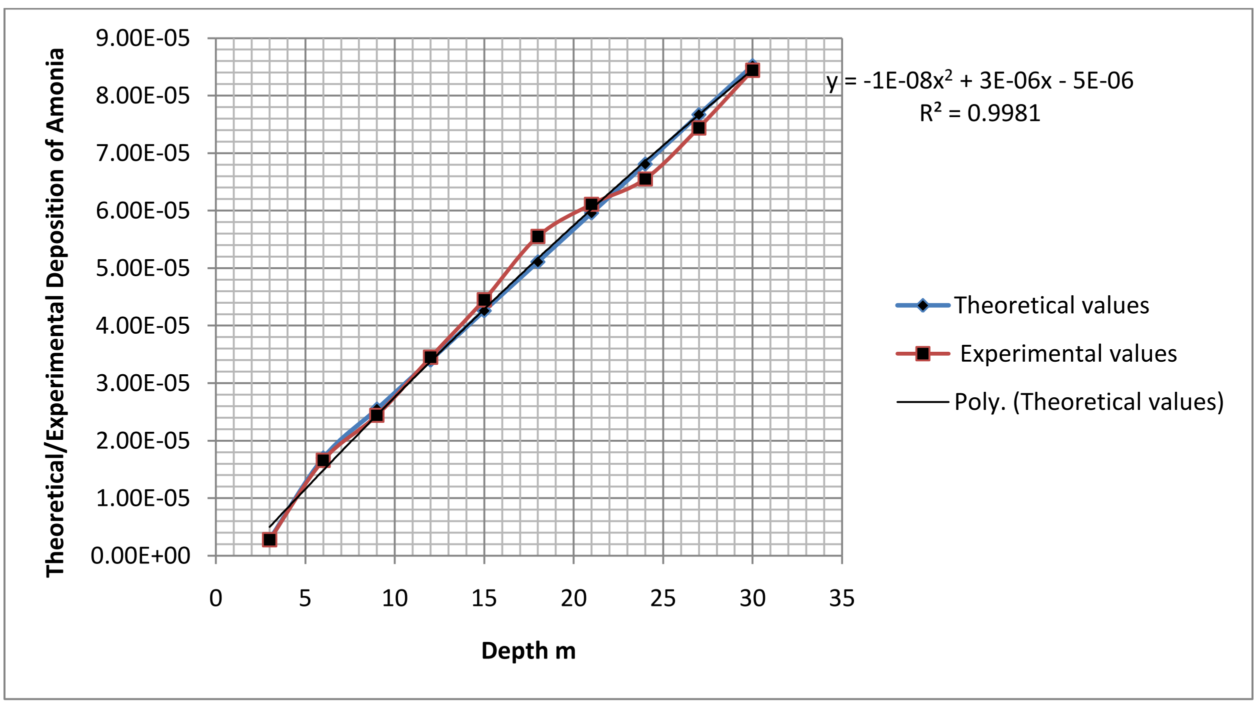

Fig. 3. Comparison of theoretical and experimental values of partial deposition of ammonia at various depths.

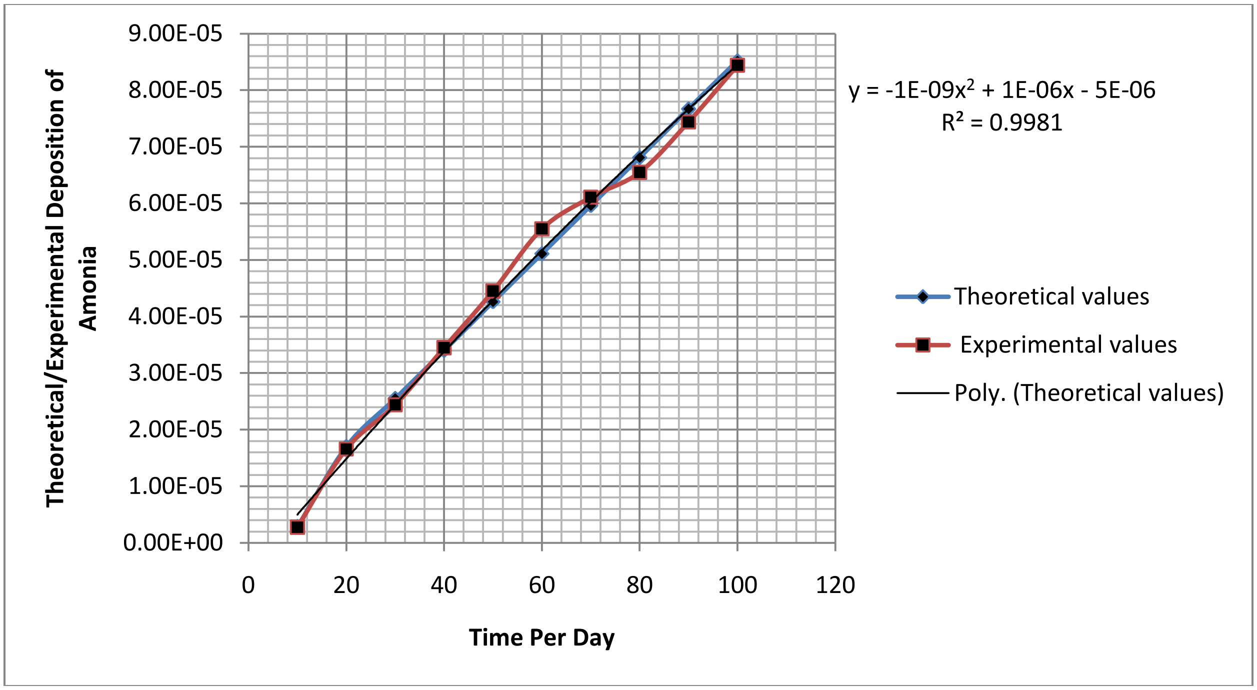

Fig. 4. Comparison of theoretical and experimental values of partial deposition of ammonia at various depths.

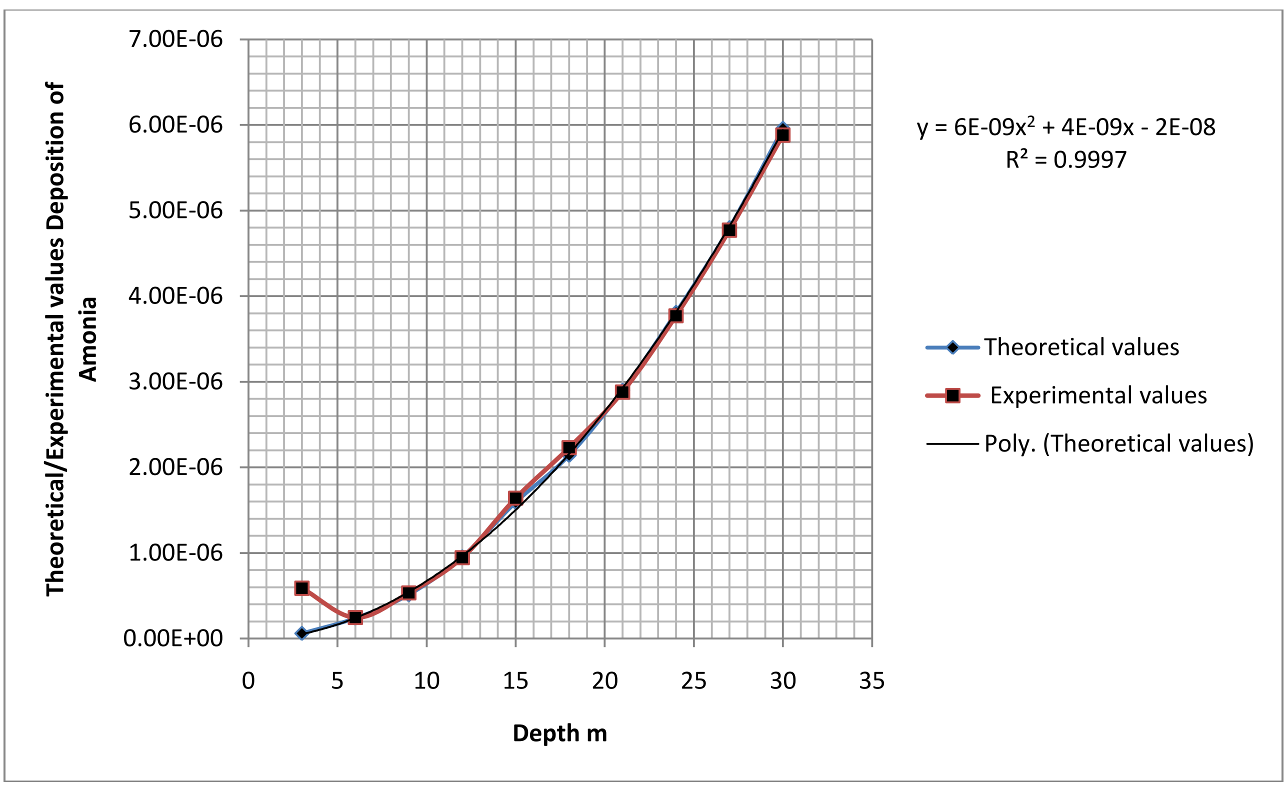

Fig. 5. Comparison of theoretical and experimental values of partial deposition of ammonia at various depths.

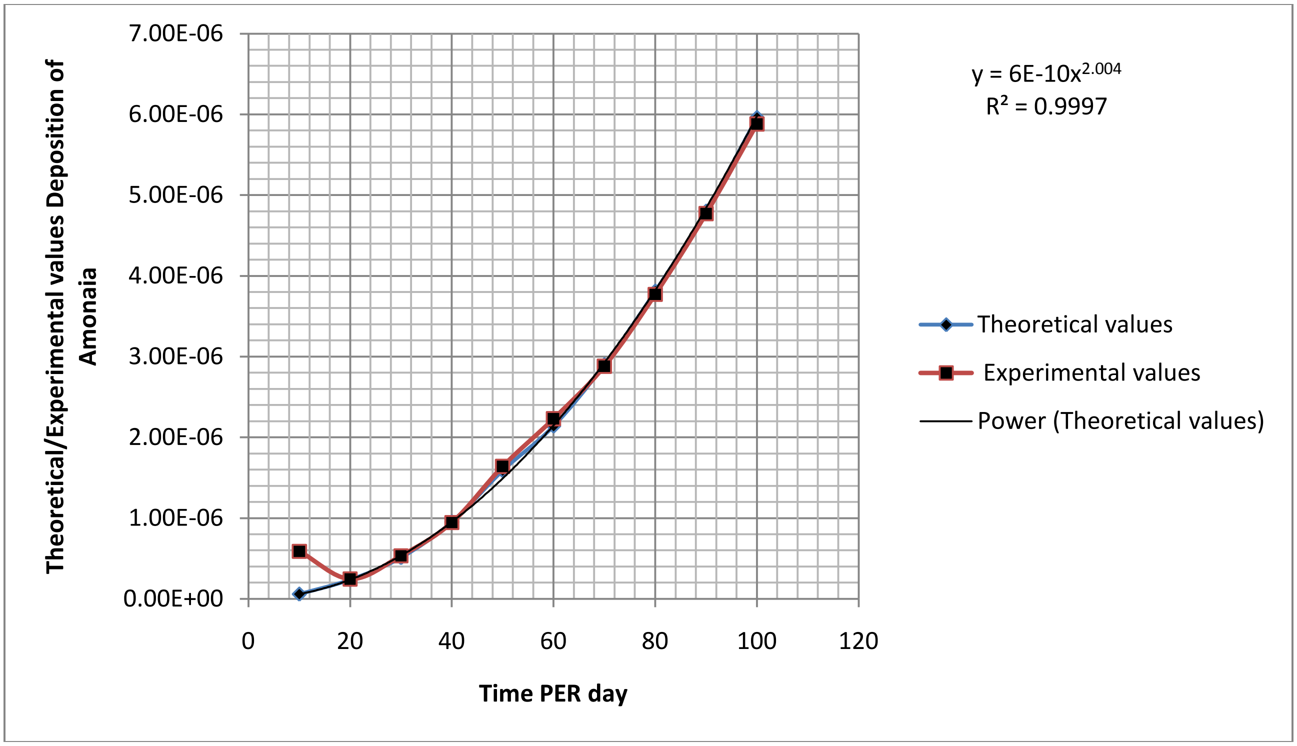

Fig. 6. Comparison of theoretical and experimental values of partial deposition of ammonia at various depths.

From figure one to six the deposition of ammonia are found to be in exponential phase as presented in the figures, the growth rate of ammonia shows that the deposition of other influences generated the fast deposition of ammonia as presented in the figures. Slight fluctuations were experienced in between the fine and coarse sand at forty to sixty days within twelve and eighteen metres on both parameters of theoretical and experimental values. Porosity and permeability expressed their influence based on high degree of depositions between the silt strata formation to coarse formation from twelve metres to thirty metres. This influence generated the migration with high concentration in some figures, but at the aquiferous zone, it expresses low concentration which may be insignificant on groundwater quality, unless there is regeneration as expressed in the figures presented. The deposition of ammonia implies that areas where there is high concentration will definitely generate increase of microbial population that will contaminate groundwater aquifers in the study location. The expression of ammonia deposition from the developed model shows that the rates of concentration coefficient of inhibition were insignificant as inhibitors deposition were found to be very low at various formations. Results at aquiferous zone can be compared to World Health Organization to determine its quality for human consumption. The study is imperative because the model can be applied to monitor partial depositions of ammonia within the influence of coefficient inhibition as it reflects fast migration of microbes to groundwater aquifer. Practicing engineers, scientists and public health officers will use this concept to monitor the growth rate of microbial contaminant in groundwater aquifers.

4. Conclusion

Partial deposition of ammonia and specific growth rate of bacterial in homogenous formation has been expressed. Expressed equations were derived and it generated a model equation for partial deposition of ammonia and specific growth rate of bacterial in homogenous formation. This expression generated theoretical values that show the exponential \phase of ammonia with respect to growth rate of bacterial at various formations. Formation characteristics were found to influence the deposition of ammonia at various formations down to groundwater aquifers. Experimental results were compared with theoretical values and it expressed a best fit in all the figures presented, this implies that the model can be applied to monitor the partial deposition of ammonia and growth rate of bacterial on homogenous formation. Geologic history expressed alluvium deposition found to be homogeneous formation generated a homogenous soil stratum that expressed its influence on the partial deposition of ammonia and specific growth rate in the study location. The study is imperative because it has shown how homogeneous formations play a major role on partial deposition of ammonia and specific growth rate of bacteria in homogeneous stratum.

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