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Research article

MODEL EVALUATION TO PREDICT NITROGEN DEPOSITIONS INFLUENCED BY POROSITY AND CADMIUM INHIBITION IN COASTAL AREA OF PORT HARCOURT.

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Abstract

Model evaluation to predict nitrogen depositions influenced by porosity and cadmium inhibition has been expressed. The study was to monitor the rate of nitrogen deposition under the influence of cadmium in coastal area of Port Harcourt, the stratification of the soil were thorough assessed through risk assessment carried out in the study location, the rate of nitrogen were found to inhibit cadmium in the study area, it was only a location that cadmium inhibit nitrogen which is insignificant on general assessment, this condition implies that such high deposition of substrate will definitely increase the deposition of microbes in the study location, thus increase ground water pollution in the study area. The study is imperative because water and environmental engineers will find it valuable in preventing ground water pollution from deposition of nitrogen in the study area.

Keywords: model evaluation, nitrogen depositions porosity and cadmium inhibition

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1. Introduction

According to the Framework for Action on Water and Sanitation (WEHAB working Group, August 2002 at the

Johannesburg 2002 World Summit on Sustainable Development), poor water quality continues to pose a major threat to human health and faecal contamination in water is still the pollutant that most seriously affects the health of children. Diarrhea, cholera, typhoid and schistosomiasis are the leading water-borne diseases. Some 200 million people world-wide have schistosomiasis, of which 20 million suffer severe consequences. Diarrhea diseases, a result of lack of adequate water and sanitation services, in the past 10 years have killed more children than all people lost to armed conflict since World War II. In general, aquifer passage reduces pathogenic microorganism concentrations, and numerous successes have been reported in cases, like artificial recharge schemes or riverbank filtration projects, where microorganisms were completely removed. However, studies in the USA have shown that up to half of all US drinking water wells tested had evidence of fecal contamination and an estimated 750,000 to 5.9 million illnesses and 1400-9400 deaths per year may result from contaminated groundwater's (Macler and Merkle, 2000). Figures on illnesses and deaths as a result from contaminated groundwater's for the developing world are not available. However, in Africa around 80% of the population in the largest cities (in Asia: around 55%) have on-site sanitation, such as septic tanks, pour-flush, VIP latrines or simple pits (World Health Organization, 2000-2003), and, according to Foster (2000), in developing countries in Asia, South America and Africa for an estimated 1,300 million persons living in urban areas, the main source of drinking water is groundwater. Groundwater may be contaminated, when wastewater infiltrates into the soil and recharges groundwater via leaking sewerage systems, leakage from manure, wastewater or sewage sludge spread by farmers on fields, waste from animal feedlots, waste from healthcare facilities, leakage from waste disposal sites and landfills, or artificial recharge of treated waste water. If the distance from source of pollution to point of abstraction is small, there is a real chance of abstracting pathogens. To predict the presence of pathogens in water, usually a separate group of microorganisms is used. The common descriptive term for this group of organisms is fecal indicator organisms (Medema et al., 2003), from which *Escherichia coli* (or *E. coli*) and thermotolerant coliform bacteria are two important members. *E. coli* is widely preferred and used as an index of fecal contamination (World Health Organization, 2003), because its detection is relatively simple, fast and reliable, and the organism is routinely measured in water samples throughout the world. The same applies to thermotolerant ('fecal') coliforms. Romero, 1970; Lewis et al., 1980; Hagedorn et al., 1981; Crane and Moore, 1984; Bitton and Harvey, 1992; Stevik et al., 2004). Others mainly focus on first-order die-off rates, thereby neglecting the transport component including attachment and detachment processes (e.g. Reddy et al., 1981; Barcina et al., 1997). Murphy and Ginn (2000) mainly summarize the mathematical descriptions of the various physico-chemical and biological processes involved in the transport of bacteria and viruses, without indicating the relative importance of these processes and their occurrence in the natural environment. Merkli (1975) and Althaus et al. (1982) have presented a comprehensive bacteria transport model based on the colloid filtration theory (Herzig et al., 1970; Yao et al., 1971), including the effects of dispersion, diffusion, sedimentation, and filtration. The effects of retardation due to equilibrium adsorption were also included, as well as the physical, chemical, and biological factors determining the die-off of pathogens and indicator organisms.

3.0 Materials and method

The column was set up; the height is metre of 100mm diameter steel pipe, positioned at vertical level, including a funnel of 30cm that contains 4 litres of waste water. Each sample level of average of 2000mg/l of waste water containing *nitrogen* was poured inside the column. While the flow was passing through the column, a stop watch was used to monitor the speed level, to determine the level of transport of each sample of aquifer materials. The effluent 1000mg/l from the column were collected and subjected to thorough analysis to determine the level of transport of *nitrogen* in each of the aquifer material, which determines the level of transport to aquiferous zone.

3.1 Bacteriological Testing of Water

Methodology: Membrane filtration. (WHO, 1993, 1996, 1998): the standard stipulated by the public health institution. To ensure that the contaminant rate migrating to ground water aquifers are known, the processes are expressed below.

A 100ml water sample was filtered through membrane filters. The membranes, with the coliform organism (*E. coli*) on it, are then cultured on a pad of sterile selective broth containing lactose and an indicator. After incubation, the number of colonies of coliform (*E. coli*) were counted. This gives the presumptive number of *E. coli* in the 100ml water sample.

3.2 Choice of Technique

The method is recommended for its accuracy, speed of result, and because it can be performed in the field. The process of this analysis is to ensure the true representative of the contaminants from the study locations.

Required:

1. Sterile filtration unit for holding 47mm diameter membrane filters with suction device (wagteck international)
2. Sterile grid membrane filters of 47mm diameter with a pore size of 0.45um (oxide).
3. Sterile 47mm diameter cellulose pads (both culture medium to be added just before use).
4. Sterile Petri dishes 50-60mm diameter
5. Sterile membrane lauryl sulphate broth (lactose sodium lauryl sulphate broth)
6. Autoclaving unit, blunt ended forceps, sterile bottles, grease pencil, incubator at 44^{o}c, Bunsen burner, Petri-dish holders and oblique light source.

Procedure:

a. **Assembling the Filtration Unit:** The sterile broth is aseptically added to the cellulose pad in a Petri-dish. The membrane filter is aseptically removed from the sterile pack using a flame sterilized blunt forceps and placed on the filter base with the grid-side uppermost and centrally. Next, the filter lid was screwed into place.

b. **Suction Filtration of Water Sample:** 100ml of the different water samples were thoroughly mixed by inverting the bottles several times and gently poured into the assembled filtration unit.

- The water was drawn into the filter membrane by suction using the hand held pressure pump.
- A blunt-ended forceps was sterilized by naked Bunsen flame, cooled and the membranes were aseptically removed from the filtration unit after unscrewing the lid of the filtration unit.
- The membranes were placed, grid-side uppermost, on the culture medium pads in the Petri-dishes, ensuring there were no air bubbles trapped under the membranes.
- The Petri-dishes were closed and the top of the lids were labelled with the code numbers of the water samples and volumes of water used using a grease pencil.

3.3 Incubation of Samples

- The Petri-dishes were packed in Petri dish holders with lids uppermost and placed inside the incubator at 44^{o}c for 12 – 16 hours. It is imperative because it produces the rate of microbial deposition in the stratum.

Examination, count and calculation of *E.coli* colonies:

- Following incubation and using oblique lighting, the membranes were examined one after the other for yellow lactose fermenting colonies, 1-3mm in diameter. The number of colonies if any was counted. Any plink and small colonies less than 1mm in diameter were ignored. Number of colonies too numerous to count were reported as “too numerous to count” (indicative of gross contamination).
- To calculate the presumptive *E. coli* count/100ml water sample, the number of colonies counted per membrane was multiplied by 1.

3.5 Nitrogen Determination

The laboratory analysis is to monitor the rate of nitrogen deposition at different soil formation to ground water aquifers, this condition also determine the influence of the contaminants in the formations

Reagents:

1. Nitrogen standards: Stock solution (1ml = NH_4^+ - N) prepare as for distillation. Working standard (1ml = 0.001mg NH_4^+ - N) dilute the stock solution 100 times. Prepare fresh each day.

2. Sodium hydroxide, 40% w/v.

3. Sodium phenate reagent: Dissolve 50 phenols in 250ml 40% NaOH and dilute to 400ml with water. Prepare fresh each day.

4. Rochelle reagent: Dissolve 60g sodium potassium tartrate (Rochelle salt) in water and dilute to 600ml with water.

5. Sodium nitroprusside, 0.16% w/v.

6. Sodium hypochlorite solution, 5% available Cl.

Procedure:

1. Pipette 0 to 10ml working standard into 50ml volumetric flask to give a range from 0 to 0.01mg NH_4^+ - N.
2. Add blank acid digest to match the sample aliquots.
3. Pipette not more than 10ml sample digest into a 50ml volumetric flask.
4. From this point treat standards and samples in the same way.
5. Add 8ml alkaline Rochelle reagent and mix.
6. Add 1ml Na nitroprusside solution and mix.
7. Add 2ml sodium phenate reagent and mix.
8. Add 1ml sodium hypochlorite reagent, dilute to volume and mix well.
9. Leave 20 minutes in a water bath at 40^0C, and then cool.
10. Measure the optical density at 625nm or use an orange filter, using water as a reference.
11. Prepare a calibration curve from the standard values and use it to obtain mg NH_4^+ - N in the sample aliquot.
12. Carry out blank determination in the same way and subtract where necessary.

Calculation:

If C = mg NH_4^+ - obtained from the graph then for:

$$N\ (\%) = \frac{C(mg) \times solution\ volume\ (ml)}{10 \times aliquot\ (ml)\ sample\ wt\ (g)}$$

3.4Theoretical Background

Theoretical background for 3rd degree polynomial curve fitting

General: $y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + \ldots\ldots\ldots + a_n x^n$

If the above polynomial fits the pair of data (x, y) it means that every pair of data will satisfy the equation (polynomial).

Thus;
$$y_1 = a_0 + a_1 x_1 + a_2 x_1^2 + a_3 x_1^3 + \ldots\ldots\ldots + a_n x_1^n \quad (1)$$

$$y_2 = a_0 + a_1 x_2 + a_2 x_2^2 + a_3 x_2^2 + \ldots\ldots\ldots + a_n x_2^n \quad (2)$$

$$y_3 = a_0 + a_1 x_3 + a_2 x_3^2 + a_3 x_2^2 + \ldots\ldots\ldots + a_n x_2^n \quad (3)$$

$$y_4 = a_0 + a_1 x_4 + a_2 x_n^2 + a_3 x_n^2 + \ldots\ldots\ldots + a_n x_4^n \quad (4)$$

Summing all the equations will yield

$$\sum_{i=1}^{i=n} y_i = \sum a_0 + \sum_{i=1}^{i=n} a_1 x_i + \sum_{i=1}^{i=n} a_2 x_i^2 + \sum_{i=1}^{i=n} a_3 x_i^3 + \sum_{i=1}^{i=n} a_4 x_i^4 + \ldots\ldots + \sum_{i=1}^{i=n} a_n x_i^n$$

$$\sum_{i=1}^{i=n} y_i = n a_0 + a_1 \sum_{i=1}^{n} x_i + a_2 \sum_{i=1}^{n} x_i^2 + a_3 \sum_{i=1}^{n} x_i^3 + \ldots\ldots + \sum_{i=1}^{n} x_i^n \quad (5.)$$

To form the equations to solve for the constants $a_0, a_1, a_2, a_3, \ldots\ldots a_n$.

We multiply equations (5) by $x_i, x_i^2, x_i^3 \ldots\ldots\ldots x_i^n$.

Multiply equation (6) by x_i

$$x_i \sum y_i = n a_0 x_i + a_1 x_i \sum x_i + a_2 x_i \sum x_i^2 + a_3 x_i \sum x_1^3 + \ldots\ldots\ldots + a_n x_i \sum x_i^n$$

$$\sum y_i x_i = a_0 \sum x_i + a_1 \sum x_i^2 + a_2 \sum x_i^3 + a_3 \sum x_i^4 + \ldots\ldots\ldots + a_n \sum x_i^{n+1} \quad (7)$$

Multiply equation (6) by x_i^2

$$x_i^2 \sum y_i = n a_0 x_i^2 + a_1 x_i^2 \sum x_i + a_2 x_i^2 \sum x_i^2 + a_3 x_i^2 \sum x_i^3 + \ldots\ldots\ldots + a_n x_i^2 \sum x_i^n \quad (8)$$

$$\sum y_i x_i^2 = a_0 \sum x_i^2 + a_1 \sum x_i^3 + a_2 \sum x_i^4 + a_3 \sum x_i^5 + \ldots\ldots + a_n \sum x_i^{n+2} \quad (9)$$

Multiply equation (3.84) by x_i^3

$$x_i^3 \sum y_i = n a_0 x_i^3 + a_1 x_i^3 \sum x_i + a_2 x_i^3 \sum x_i^2 + a_3 x_i^3 \sum x_i^3 + \ldots\ldots + a_n x_i^3 \sum x_i^n$$

$$\sum y_i x_i^3 = a_0 \sum x_i^3 + a_1 \sum x_i^4 + a_2 \sum x_i^5 + a_3 \sum x_i^6 + \ldots\ldots + a_n \sum x_i^{n+3} \quad (10.)$$

Multiply equation (5,6 and 7) by x_i^n

$$x_i^n \sum y_i = a_0 n x_i^n + a_1 x_i^n \sum x_i + a_2 x_i^n \sum x_i^2 + a_3 x_i^n \sum x_i^3 + \ldots\ldots + a_n x_i^n \sum x_i^n$$

$$= a_0 \sum x_i^n + a_1 \sum x_i^{n+1} + a_2 \sum x_i^{n+2} + a_3 \sum x_i^{n+3} + \ldots\ldots + a_n \sum x_i^{n+n} \quad \ldots\ldots\ldots \text{ n}$$

Putting equations (5, 6, 7, 8, and 9) to n into matrix form

$$\begin{bmatrix} n & \sum x_i & \sum x_i^2 & \sum x_i^3 & \ldots\ldots \sum x_i^n \\ \sum x_i & \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \ldots\ldots \sum x_i^{n+1} \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \ldots\ldots \sum x_i^{n+2} \\ \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \sum x_i^6 & \ldots\ldots \sum x_i^{n+3} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \sum x_i^n & \sum x_i^{n+1} & \sum x_i^{n+2} & \sum x_i^{n+3} \ldots . \sum x_i^{n+n} & \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \\ \ldots . \\ a_n \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum y_i x_i \\ \sum y_i x_i^2 \\ \sum y_i x_i^3 \\ \ldots \\ \sum y_i x_i^n \end{bmatrix}$$

Solving the matrix equation yields values for constants $a_0, a_1, a_2, a_3, \ldots\ldots a_n$ as the case may be depending on the power of the polynomial.

From the above matrix; for our particular case; i.e. polynomial of the third order:

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 \quad (11)$$

The equivalent matrix equation will be; ($n = 3$).

$$\begin{bmatrix} n & \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \sum x_i^5 \\ \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \sum x_i^6 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum y_i x_i \\ \sum y_i x_i^2 \\ \sum y_i x_i^3 \end{bmatrix}$$

4. Results and Discussion

Results of theoretical values of nitrogen deposition and inhibition from cadmium are presented in tables and figures bellow.

Table 1: Comparison of Theoretical and Experimental Values at Different Depths

Depth (m)	Theoretical Model	Experimental values
3	1.27E-03	1.21E-03
6	2.50E-03	2.35E-03
9	3.74E-03	3.52E-03
12	4.99E-03	4.55E-03
15	6.27E-03	5.80E-03
18	7.56E-03	7.44E-03
21	8.86E-03	8.10E-03
24	1.00E-02	9.22E-03
27	1.20E-02	1.14E-02
30	1.30E-02	1.18E-02

Table 2: Comparison of Theoretical and Experimental Values at Different Depths

Depth (m)	Theoretical Model	Experimental values
3	3.30E-04	3.31E-04
6	3.15E-03	3.15E-03
9	9.35E-04	8.52E-04
12	1.24E-03	1.55E-03
15	1.54E-03	1.80E-03
18	1.85E-03	1.44E-03
21	2.16E-03	2.10E-03
24	2.47E-03	2.22E-03
27	2.78E-03	2.14E-03
30	3.10E-03	3.18E-03

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

Depth (m)	Theoretical Model	Experimental values
3	1.30E-03	1.21E-03
6	2.55E-03	2.35E-03
9	3.82E-03	3.52E-03
12	5.10E-03	4.55E-03
15	6.37E-03	5.80E-03
18	7.64E-03	7.44E-03
21	8.90E-03	8.10E-03
24	1.00E-02	9.22E-03
27	1.10E-02	1.14E-02
30	1.20E-02	1.18E-02

Table 4: Comparison of Theoretical and Experimental Values at Different Depths

Depth (m)	Theoretical Model	Experimental values
3	2.59E-04	3.31E-04
6	5.59E-04	5.15E-04
9	8.58E-04	8.52E-04
12	1.15E-03	1.55E-03
15	1.45E-03	1.30E-03
18	1.75E-03	1.64E-03
21	2.10E-03	2.10E-03
24	2.34E-03	2.22E-03
27	2.62E-03	2.54E-03
30	2.94E-03	3.18E-03

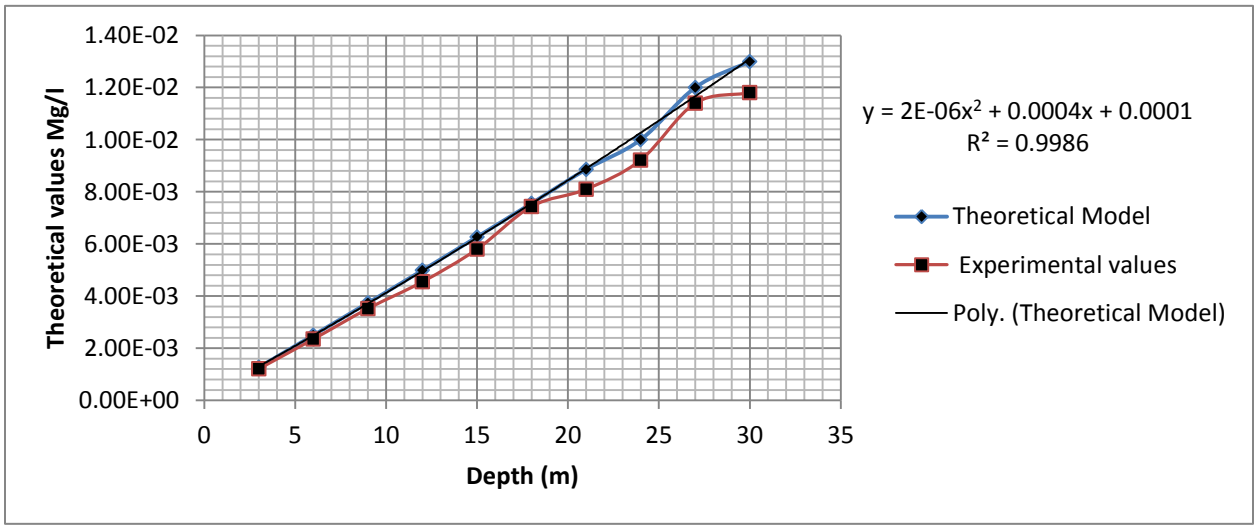

Figure 1: Comparison of Theoretical and Experimental Values at Different Depths

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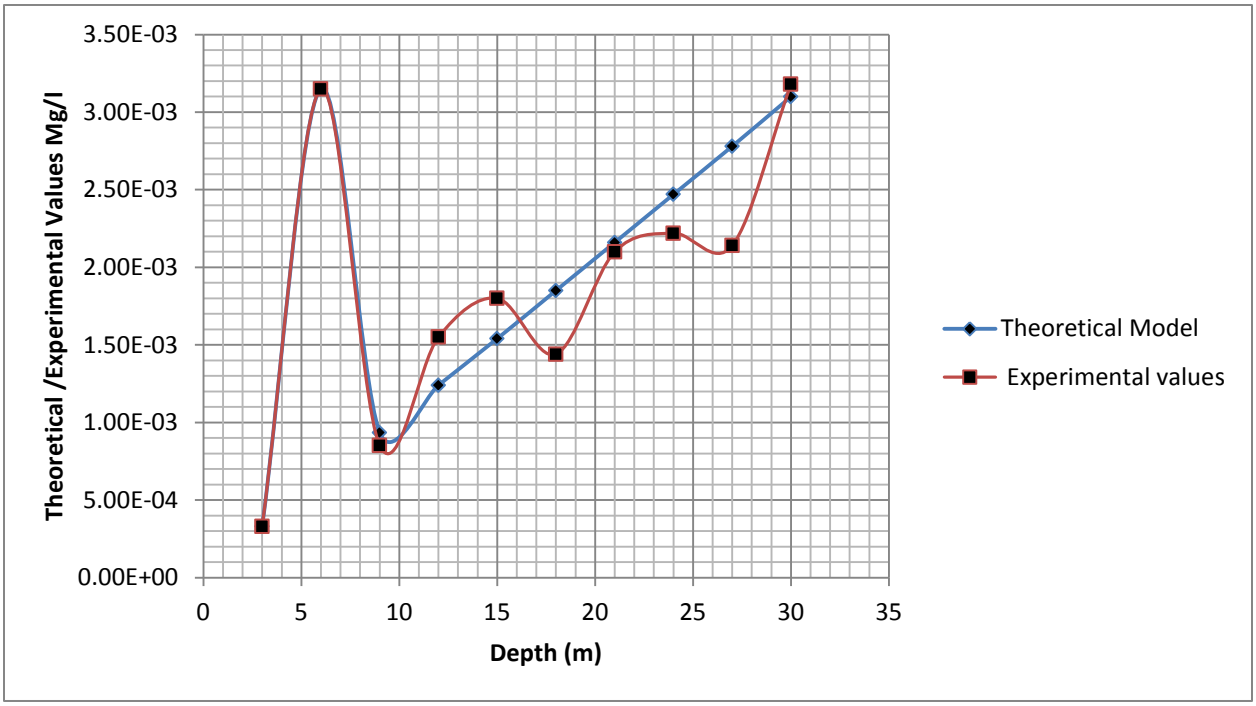

Figure 2: Comparison of Theoretical and Experimental Values at Different Depths

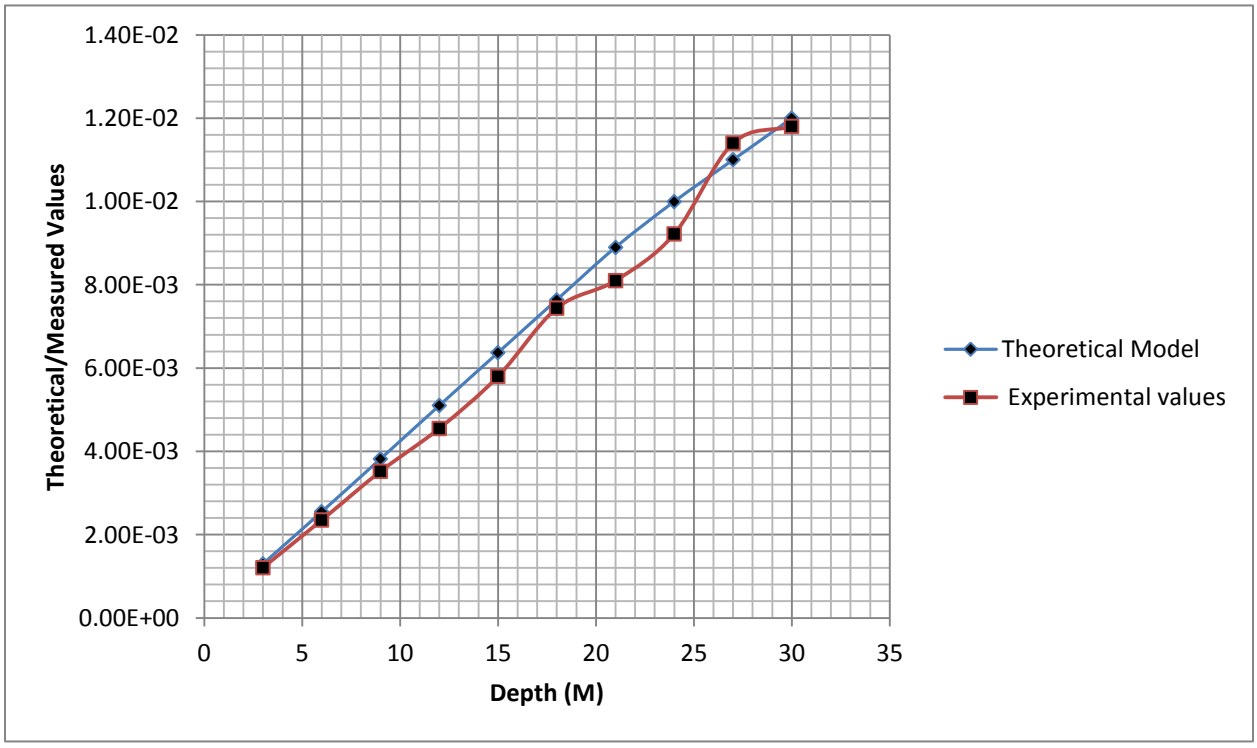

Figure 2Comparison of Theoretical and Experimental Values at Different Depths

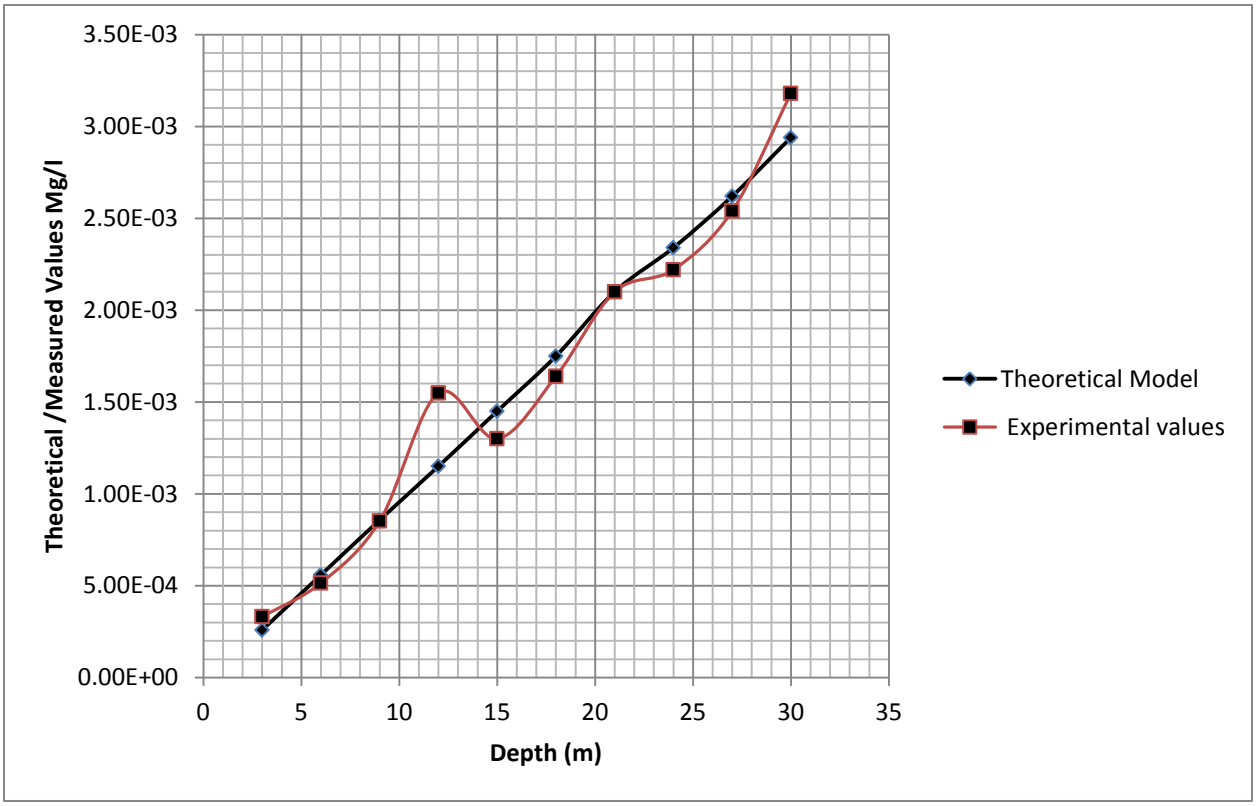

Figure 4: Comparison of Theoretical and Experimental Values at Different Depths

Figure one shows how it linearly increase in a gradual process to where the optimum values were recorded at thirty metres, while that of the experimental values express similar conditions, but developed slight fluctuation between twenty-one and thirty metres where an optimum values was obtained. This condition implies that the substrate nitrogen deposit high concentration and were able to inhibit the heavy metals cadmium within the organic soil in coarse and gravel formations where aquiferous zone are established. Figure two express different condition from that of figure one, the substrate nitrogen rapidly increase with depths from three to nine metres where it linearly develop another increase with depths to the point where an optimum value was recorded, similarly condition were observed on the experimental values, rapid increase were experienced from three to six metres, sudden decrease were also experienced at nine metres, while fluctuation were observed between twelve to thirty metres in exponential condition, developing an optimum values at thirty metres respectively. This condition shows the rate of variations on nitrogen deposition in soil and water environments base degradations of nitrogen's, under the influence of high concentrations of microbial growth in those formations, more so it also implies that the inhibition from heavy metal like cadmium may have influence the deposition rate of nitrogen developing variation between twelve and thirty metres, this can be attributed to change in concentration influenced by the degree of porosity of the soil in deltaic environments. Figure three shows that the substrate linearly increased from the lowest at three metres, thus to the optimum value, recorded at thirty metres, while that of the experimental values observed linear increase between three and fifteen metres and finally experienced fluctuation from eighteen to thirty metres where the

optimum values were recorded, figure four observed linear increase from three to nine metres and finally express fluctuation from twelve to thirty metres, while theoretical values developed linear increase from the lowest at three metres to the optimum at thirty metres, this condition shows the level of deposition and inhibition of heavy metals cadmium in the study area, few area in the study location observed heavy metal cadmium inhibiting the substrate nitrogen in the study area, this implies that microbes may have increase in population in those formations, but with the rate of concentration from nitrogen at organic soil to aquiferous zone of coarse sand formation, there rates will be compared with world health organization if water quality from those aquiferous zone will be good for human consumption, the model will definitely assist practicing engineers in this directions.

4. Conclusion

The rate nitrogen deposition in soil and water environment has been evaluated, this is to conceptualize the influence from nitrogen deposition and inhibition level at different stratification of the strata, the concept were expresses through developed model that generate theoretical values to conceptualized the behaviour of both parameters in the system, the rate of nitrogen were observed to developed upper hand in inhibition process in the study locations., few area were observed were cadmium developed inhibition on deposition of nitrogen in the study location, such deposition of nitrogen implies that substrate are found to be predominant in the study area, these conditions implies that if microbes found to deposit in such environment they will certainly increase in microbial population , therefore it is important to note this condition on the deposition of nitrogen in the study locations.

References

[1] Althaus, H., K.D. Jung, G. Matthess and A. Pekdeger, 1982. Lebensdauer von Bacterien und Viren in Grundwasserleitern. Umweltbundesamt, Materialien 1/82. Schmidt-Verlag, Berlin.

[2] Crane, S.R. and J. Moore, 1984. Bacterial pollution of groundwater: a review. Water, Air , Soil Pollution (22), p. 67-83.

[3] Foster, S.S.D., 2000. Groundwater resources at the turn of the millennium: taking stock and looking forward. In: *Groundwater: past achievements and future challenges, Sillo et al. (eds.),* Balkema, Rotterdam, The Netherlands, ISBN 90 5809 159 7

[4] Hagedom C.E.I, McCoy and T.M, Rahe, 1981, the potential for Quality water contaminant from septic effluents, j Environ Qual (10).p1-8

[5] Barcina, I., P. Lebaron and J. Vives-Rego, 1997. Survival of allochthonous bacteria in aquatic systems: a biological approach. FEMS Microbiol. Ecol. (23), p. 1-9.

[6] Bitton, G., S.R. Farrah, R.H. Ruskin, J. Butner and Y.J. Chou, 1983. Survival of pathogenic and indicator organisms in ground water. Ground Water (21), p. 405-410.

[7] Macler, B.A. and J.C. Merkle, 2000. Current knowledge on groundwater microbial athogens and their control. Hydrogeol. J. (2000), vol. 8, no. 1, pp. 29-40.

[8] Murphy, E.M., J. M. Zachara, and S. C. Smith, 1990. Influence of mineral-bound humic bstances onhe sorption

of hydrophobic organic compounds. Environ. Sci. Technol., Vol. 24, p. 1507-1516.

[9] Medema, G.J., P. Payment, A. Dufour, W. Robertson, M. Waite, P. Hunter, R. Kirby and Y. Andersson, 2003. Safe drinking water: an ongoing challenge. In: *Assessing microbial safety of drinking water: improving approaches and methods, Dufour et al. (eds.).* World Health Organization, 2003. ISBN 92 4 1546

[10] Merkli, B., 1975. Untersuchungen ueber Mechanismen und Kinetik der Elimination von Bakterien und Viren im Grundwasser. Diss. ETH Zurich 5420.

[11] Ramalho, R., A. Afonso, J. Cunha, P. Teizeira and P.A. Gibbs, 2001. Survival characteristics of pathogens inoculated into bottled mineral water. Food Control (12), p. 311-316.

[12] Reddy, K.R., R. Khaleel and M.R. Overcash, 1981. Behavior and transport of microbial athogens and indicator organisms in soils treated with organic wastes. J. Environ. Qual. (10), p. 255-266.

[13] World Health Organization, 2000-2003. Global Water Supply and Sanitation Assessment 2000 Report. http://www.who.int/docstore/water_sanitation_health/globassessment.

[14] Yao, K-M, M.T. Habibian and C.R. O'Melia, 1971. Water and wastewater filtration: Concepts and Applications. Environmental Science and Technology Vol. 5, Number 11, p. 1105-1112.

[15] Stevik, T.K., K. Aa, G. Ausland and J.F. Hanssen, 2004. Retention and removal of pathogenic bacteria in wastewater percolating through porous media: a review. Wat. Res. (38), p. 1355-1367.