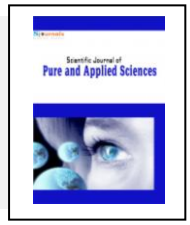
Sjournals
Scientific Journals
Scientific Journal of Pure and Applied Sciences (2012) 1(2) 46-57
ISSN 2322-2956

Contents lists available at Sjournals
Scientific Journal of
Pure and Applied Sciences
Journal homepage: www.Sjournals.com



Original article

Modeling and simulation of entric -virus transport in deltaic environment rivers state of Nigeria

S.N. Eluozo
Subaka Nigeria Limited Port Harcourt Rivers State of Nigeria.

*Corresponding author; Subaka Nigeria Limited Port Harcourt Rivers State of Nigeria.

A R T I C L E I N F O

Article history:
Received 12 November 2012
Accepted 25 November 2012
Available online 30 Nov 2012

Keywords:
Modeling
Entric-virus transport
Environment

A B S T R A C T

Modeling and simulation of entric-virus transport in deltaic environment has been evaluated. High degree of concentration of entric-virus in soil and water is a serious threat to human livelihood, the model were develop to monitor the rate of concentration at various time and depth, in other to see their behaviors at various time, the rate of degradation where found in some depth and days, it can be attributed to degradation of substrate and depth deposition of inhibitors, finally the variation of climatic condition were also found to have influence the degradation of the virus in some depth and days. This study is imperative because it will help practicing engine to beware of areas were this species of microbes are deposited it is recommended that there should be construction of treatment plant for borehole location that this type of microbe are found to deposit high concentration.

1. Introduction

Potential to move deeply through the subsurface environment, penetrate aquitard, and reach confined aquifers. Enteric viruses are extremely small (27-75 nm), readily passing through sediment pores that would trap much larger pathogenic bacteria and protozoa. Viruses have been found in groundwater at depths of 67 m (Keswick and Gerba 1980; Robertson and Edberg 1997) and 52 m (Borchardt and others 2003) and lateral transport has been reported as far as 408 m in glacial till and 1600 m in fractured limestone (Keswick and Gerba 1980).

Several recent studies have demonstrated widespread occurrence of viruses in domestic and municipal wells in the United States (Abbaszadegan and others 2003; Borchardt and others 2003; Fout and others 2003; Borchardt and others 2004), and approximately half of waterborne disease outbreaks attributable to groundwater consumption in the United States have a viral etiology (National Primary Drinking Water Regulations, 2006). The US Environmental Protection Agency has listed several viruses on its drinking water Contaminant Candidate List, emphasizing that waterborne viruses are a research priority (http://www.epa.gov/safewater/ccl/index.html). Although the vulnerability of groundwater to virus contamination is now recognized, the occurrence of viruses in confined aquifers has rarely been explicitly investigated. In the most comprehensive groundwater-virus study to date, Abbaszadegan and others (2003) sampled 448 groundwater sites in 35 states and found 141 sites (31.5%) were positive for at least one virus type.

The work reported here builds on previous virus sampling of deep groundwater in Madison, Wisconsin. During 2005 and 2006 we undertook initial virus sampling of three deep bedrock wells serving the city of Madison, Wisconsin (Borchardt and others 2007a). Each of these high-capacity wells is over 700 feet deep and cased to at least 220 feet below the surface. The vertical hydraulic gradient is downward due to a major cone of depression beneath Madison. Two of the wells (wells 7 and 24) are cased through the Eau Claire shale, a regional aquitard described by Bradbury and others (1999) and thought to provide excellent protection to the underlying sandstone aquifer. A third well (well 5, now abandoned) was open both above and below the shale. Conventional wisdom suggested that viruses would not be detected in any of the three wells due to the probable long travel times from the surface to the wells, the depths of the wells, and the assumed short (six months to two years) lifetime of the viruses. The surprising result of the study was that viruses were repeatedly detected in the two wells thought to have greatest protection due to their deep casings (wells 7 and 24). Viruses were detected in 4 of 10 samples from well 7 and 3 of 10 samples from well 24 (Borchardt and others 2007a). Moreover, five of the seven positive samples tested positive for infectivity, suggesting relatively rapid transport from the virus source to the wells. Replicate sampling and careful laboratory procedures have ruled out laboratory contamination as a source for the viruses. The human enteric viruses detected include serogroups coxsackieviruses and echoviruses as wells as poliovirus vaccine strain Sabin 1. The Madison, Wisconsin wells are typical of wells now in use in many cities throughout Wisconsin and the United States. These high-capacity wells range in age from less than five to over 50 years and were constructed according to accepted well drilling practices, which include grouted well casing to depth. The wells produce water from one or both of two aquifers. The shallow bedrock aquifer is composed of sandstone and dolomite. The deeper bedrock aquifer is composed of sandstone. A regional aquitard, the Eau Claire aquitard, is composed of shale and siltstone, and separates the two aquifers, but may contain fractures or be absent beneath the nearby Madison lakes. Although the water utility samples the wells regularly for a long list of organic and inorganic contaminants, including bacteria, the wells are not tested for viruses, presumably because viruses have not been thought to be present in the subsurface (*Kenneth et al 2010)*.

2. Materials and methods

Column experiments were also performed using soil samples from several borehole locations, the soil samples were collected at intervals of three metres each (3m). An Entric -virus solute was introduced at the top of the column and effluents from the lower end of the column were collected and analyzed for E.coli, and the effluent at the down of the column were collected at different days, for analysis,

3. Governing equation

$$Q\frac{\partial^2 C}{\partial x^2} = U\frac{\partial C}{\partial x} - \alpha k \quad \text{...} \quad (1)$$

Applying Laplace transformation into equation (1) we have

$$\frac{\partial^2 C}{\partial t^2} = S^2 C_{(x)} - SC_{(x)} - C_{(o)} \quad \text{...............................} \quad (2)$$

$$\frac{\partial C}{\partial x} = S^1 C_{(x)} - SC_{(x)} \quad \text{...............................} \quad (3)$$

$$C = C_o \quad \text{..............................} \quad (4)$$

Substituting equations (2), (3) and (4) into equation (1) yield

$$Q\left[S^2C_{(x)} - SC_{(x)} - C_{(o)}\right] - U\left[SC_{(x)} - C_{(x)}\right]\alpha k\,C_{(o)} \quad \text{..............................} \quad (5)$$

$$QS^2C_{(x)} - QSC^1{}_{(x)} - C_{(o)} - USC_{(x)} + UC_{(o)} - \alpha k\,C_{(o)} \quad \text{..............................} \quad (6)$$

Considering the following boundary condition at

$$t = 0,\ C^1{}_{(o)} = P_o = C_{(o)} = 0 \quad \text{..............................} \quad (7)$$

We have

$$C_{(x)}\left(QS^2 - QS - US\right) = 0 \quad \text{..............................} \quad (8)$$

$$C_{(x)} \neq 0 \quad \text{..............................} \quad (9)$$

Considering the boundary condition at

$$t > 0,\ C^1{}_{(o)} = C_{(o)} = C_{(o)} \quad \text{..............................} \quad (10)$$

$$S^2C_{(x)} - US_{(x)} - \alpha kC_{(x)} = QSC_o + QC_o + UC_o \quad \text{..............................} \quad (11)$$

$$\left[QS^2 - Us - \alpha k\right]C_{(x)} = \left[QS + Q + U\right]C_o \quad \text{..............................} \quad (12)$$

$$C_{(x)} = \frac{QS + Q + U}{\left[QS^2 - Us - \alpha k\right]}\,C_o \quad \text{..............................} \quad (13)$$

Applying quadratic expression, we have

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad \text{..................................} \quad (14)$$

$$\frac{-U \pm \sqrt{U^2 + 4Qakc}}{2Q} \quad \text{..................................} \quad (15)$$

$$C_{(x)} = A\exp\frac{\left[-U + \sqrt{-U^2 + 4Qakc}\right]^x}{2Q} - \exp\frac{\left[-U + \sqrt{-U^2 + 4Qakc}\right]^x}{2Q} \quad \text{......................} \quad (16)$$

Subjecting equation (16) to the following boundary condition and initial values condition

$$x = 0,\ C_{(o)} = 0 \quad \text{..................................} \quad (17)$$

We have $B \quad -1 and\ A = 1$ .... (18)

So that our particular solution, will be in this form

$$C_{(x)} = \exp\left[-U + \left(U^2 - 4Qakc\right)^{1/2}\right]x - \exp\left[-U + \left(U^2 + 4Qakc\right)^{1/2}\right] \text{...........} \quad (19)$$

But $e^x + e^{-x} = 2Sin\,x$

Therefore, the expression of (19) can be of this form

$$C_{(x)} = 2Sin\left[U^2 + \left[U^2 + 4Qakc\right]^{1/2}\right]x \quad \text{.....................} \quad (20)$$

But if $x = \frac{x}{v}$

Therefore, the model can be expressed as:

$$C_t = 2Sin\left[U + \left(U^2 + 4Qakc\right)^{1/2}\right]^{\frac{v}{t}} \quad \text{........................} \quad (21)$$

Again, if $\frac{v}{t} = x$, we have

$$C_{(x)} = 2Sin\left[U + \left(U^2 + 4Qakc\right)^{1/2}\right]x \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

Considering (21) and (22) yield

$$\left(C_{x,t}\right) = 2Sin\left[U + \left(U^2 + 4Qakc\right)^{1/2}\right] + 2Sin\left[U + \left(U^2 + 4Qakc\right)^{1/2}\right]x \quad \ldots\ldots\ldots \quad (23)$$

Applying quadratic expression, we have

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

$$\frac{-U \pm \sqrt{U^2 + 4Qakc}}{2Q} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

$$C_{(x)} = A\exp\frac{\left[-U + \sqrt{-U^2 + 4Qakc}\right]^x}{2Q} - \exp\frac{\left[-U + \sqrt{-U^2 + 4Qakc}\right]^x}{2Q} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

Subjecting equation (16) to the following boundary condition and initial values condition

$$x = 0,\ C_{(o)} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

We have $B \quad -1 and\ A = 1$ ……………………………… (18)

So that our particular solution, will be in this form

$$C_{(x)} = \exp\left[-U + \left(U^2 - 4Qakc\right)^{1/2}\right]x - \exp\left[-U + \left(U^2 + 4Qakc\right)^{1/2}\right] \ldots\ldots\ldots \quad (19)$$

But $e^x + e^{-x} = 2Sin\, x$

Therefore, the expression of (19) can be of this form

$$C_{(x)} = 2Sin\left[U^2 + \left[U^2 + 4Qakc\right]^{1/2}\right]x \quad \ldots\ldots\ldots\ldots\ldots \quad (20)$$

But if $x = \frac{x}{v}$

Therefore, the model can be expressed as:

$$C_t = 2Sin\left[U + \left(U^2 + 4Qakc\right)^{1/2}\right]^{\frac{v}{t}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

Again, if $\frac{v}{t} = x$, we have

$$C_{(x)} = 2Sin\left[U + \left(U^2 + 4Qakc\right)^{1/2}\right]x \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

Considering (21) and (22) yield

$$\left(C_{x,t}\right) = 2Sin\left[U + \left(U^2 + 4Qakc\right)^{1/2}\right]t + 2Sin\left[U + \left(U^2 + 4Qakc\right)^{1/2}\right]x \quad \ldots\ldots \quad (23)$$

4. Results and discussion

Tables and figures of Entric -virus transport in deltaic environment are presented bellow

Table 1

Comparison of theoretical and experimental values at various times.

Time	Theoretical values	Experimental value
10	0.04	0.038
20	2.04E-04	2.11E-04
30	1.36E-04	1.37E-04
40	1.02E-04	1.11E-04
50	8.16E-05	*8.23E-05*
60	6.78E-05	7.02E-05
70	5.81E-05	5.88E-05
80	5.11E-04	5.33E-05
90	4.49E-05	4.53E-05
100	4.09E-03	4.11E-05
110	3.72E-04	3.84E-04
120	3.41E-03	3.51E-03

Table 2

Comparisons of theoretical and experimental values at various depths.

Depth m	Theoretical values	Experimental value
3	0.04	0.038
6	2.04E-04	2.11E-04
9	1.36E-04	1.37E-04
12	1.02E-04	1.11E-04
15	8.16E-05	*8.23E-05*
18	6.78E-05	7.02E-05
21	5.81E-05	5.88E-05
24	5.11E-04	5.33E-05
27	4.49E-05	4.53E-05
30	4.09E-03	4.11E-05
33	3.72E-04	3.84E-04
36	3.41E-03	3.51E-03

Table 3

Comparisons of theoretical and experimental values at various time.

Time	Theoretical values	Experimental value
10	2.41E-04	2.47E-04
20	1.22E-04	1.32E-04
30	8.11E-05	8.44E-04
40	6.14E-04	6.45E-04
50	4.91E-04	5.11E-04
60	4.09E-04	4.11E-04
70	3.51E-04	3.53E-04
80	3.07E-04	3.07E-04
90	2.72E-04	2.88E-04
100	2.43E-04	2.22E-04

Table 4
Comparisons of theoretical and experimental values at various depths.

Depth m	Theoretical values	Experimental value
3	2.41E-04	2.47E-04
6	1.22E-04	1.32E-04
9	8.11E-05	8.44E-04
12	6.14E-04	6.45E-04
15	4.91E-04	5.11E-04
18	4.09E-04	4.11E-04
21	3.51E-04	3.53E-04
24	3.07E-04	3.07E-04
27	2.72E-04	2.88E-04
30	2.43E-04	2.22E-04

Table 5
Theoretical and values at various time.

Time	Theoretical values
10	0.04
20	2.04E-04
30	1.36E-04
40	1.02E-04
50	8.16E-05
60	6.78E-05
70	5.81E-05
80	5.11E-04
90	4.49E-05
100	4.09E-03
110	3.72E-04
120	3.41E-03

Table 6
Theoretical and values at various times.

Depth m	Theoretical values
3	0.04
6	2.04E-04
9	1.36E-04
12	1.02E-04
15	8.16E-05
18	6.78E-05
21	5.81E-05
24	5.11E-04
27	4.49E-05
30	4.09E-03
33	3.72E-04
36	3.41E-03

Table 7
Theoretical and values at various times.

Depth m	Theoretical values
3	2.41E-04
6	1.22E-04
9	8.11E-05
12	6.14E-04
15	4.91E-04
18	4.09E-04
21	3.51E-04
24	3.07E-04
27	2.72E-04
30	2.43E-04

Table 8
Theoretical and values at various times.

Time	Theoretical values
10	2.41E-04
20	1.22E-04
30	8.11E-05
40	6.14E-04
50	4.91E-04
60	4.09E-04
70	3.51E-04
80	3.07E-04
90	2.72E-04
100	2.43E-04

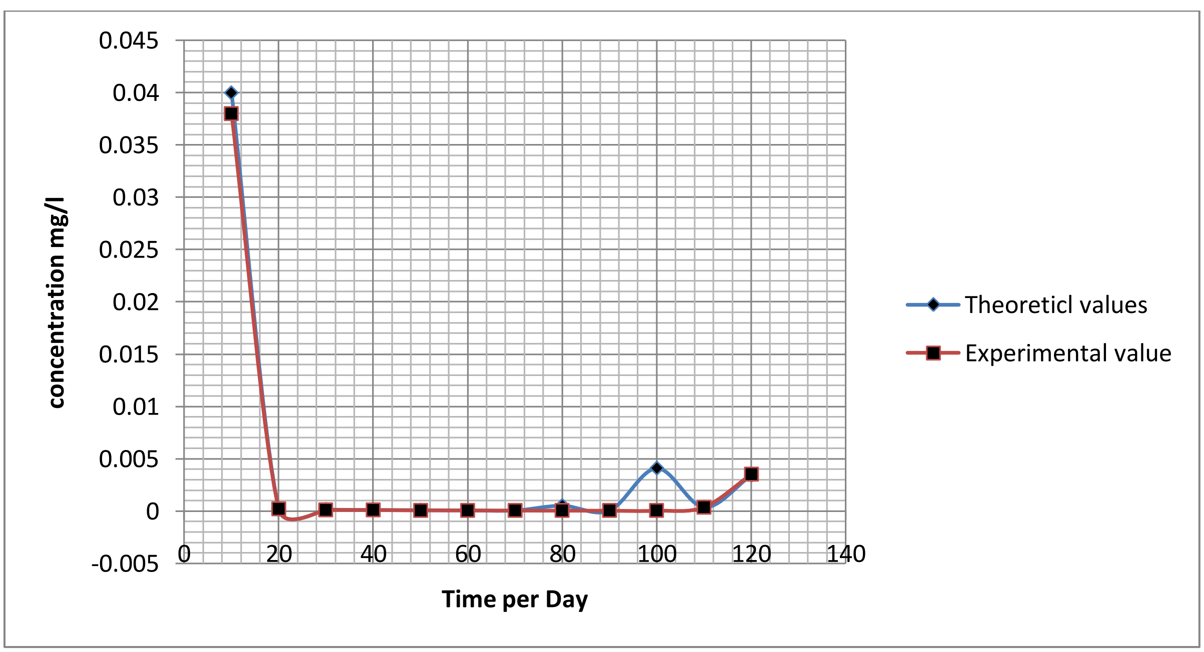


Fig. 1. Comparison of theoretical and experimental values at various depths.

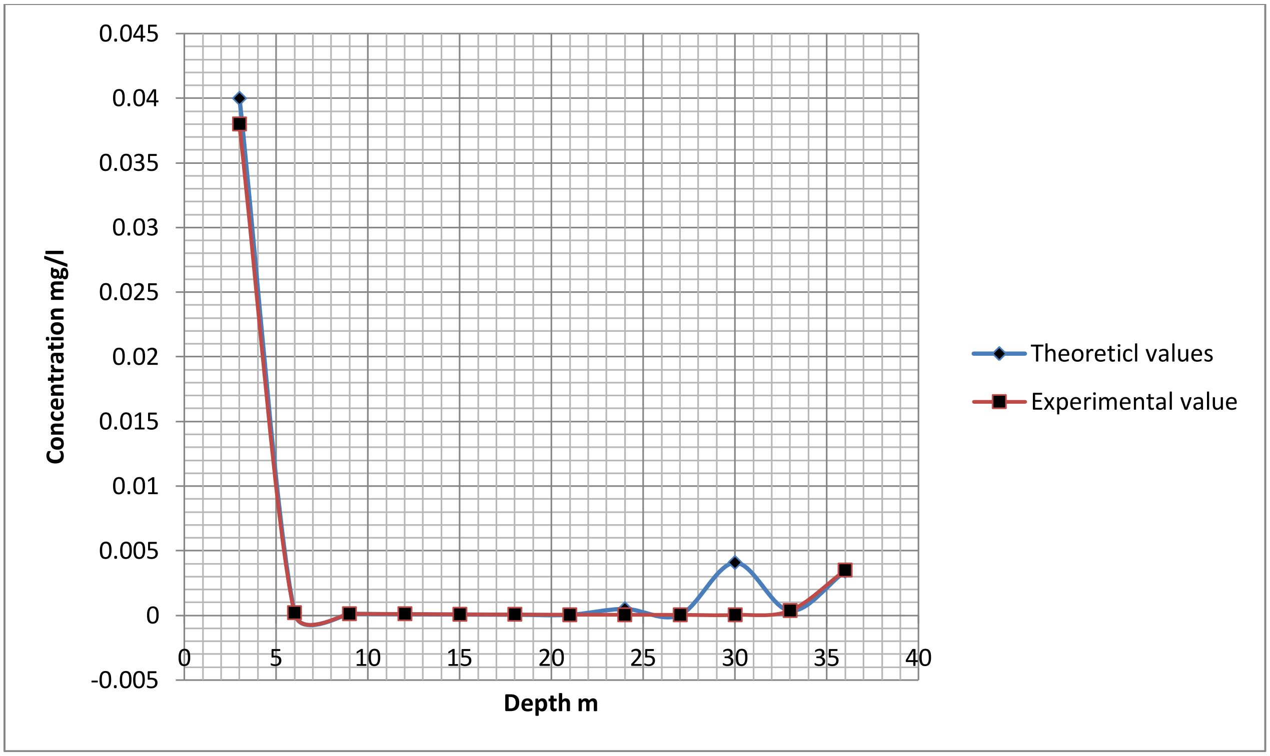


Fig. 2. Comparisons of theoretical and experimental values at various depths.

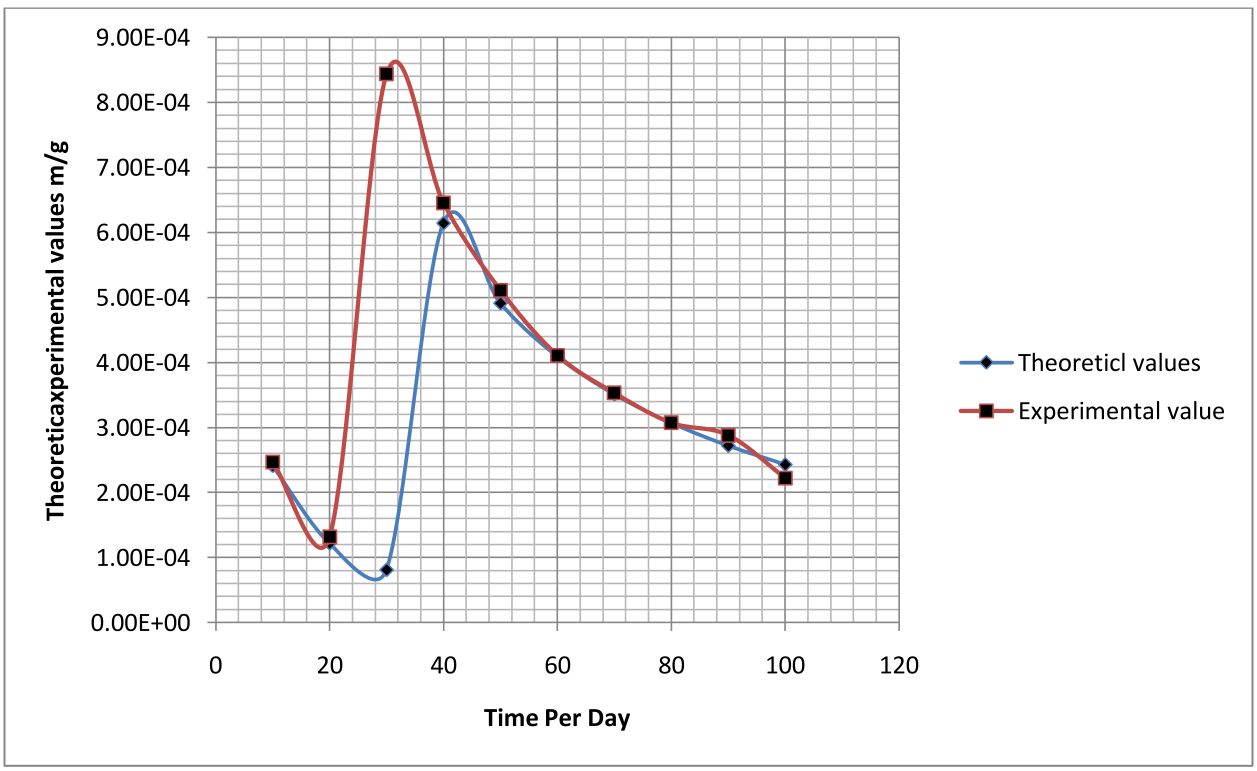


Fig. 3. Comparison of theoretical and experimental values at various times.

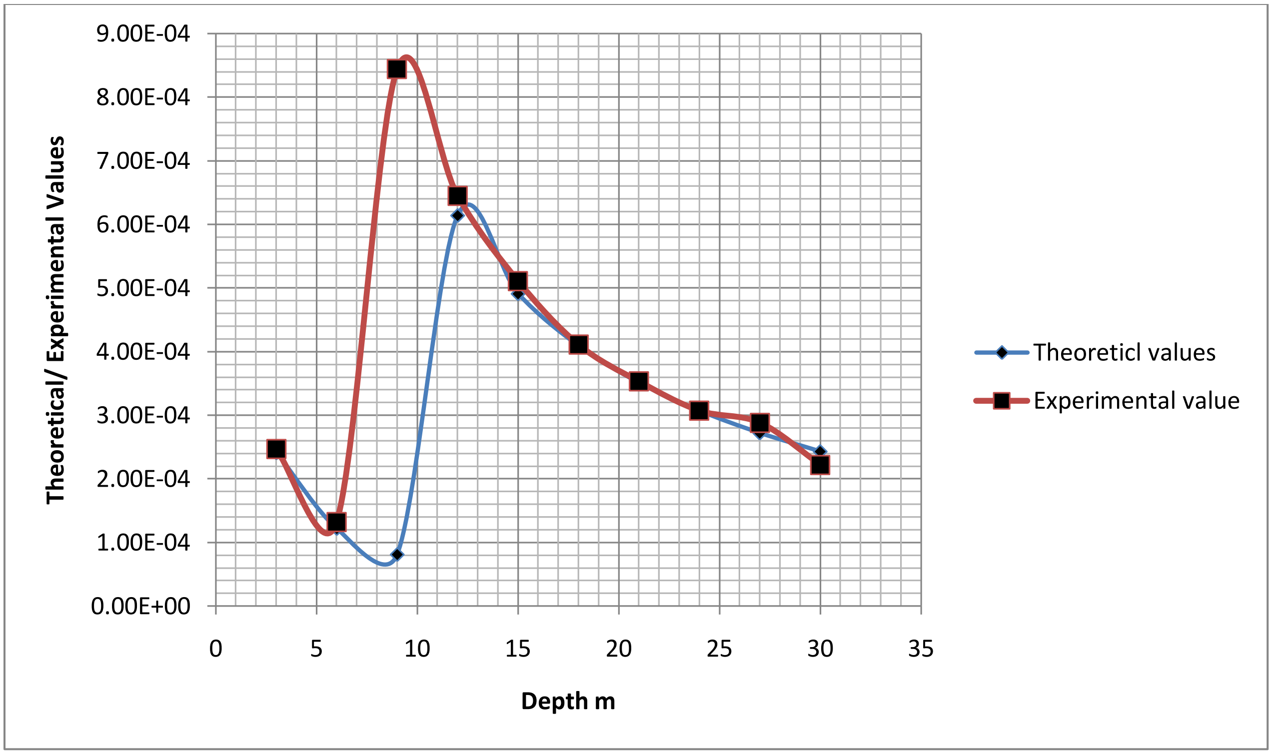


Fig. 4. Comparisons of theoretical and experimental values at various depths.

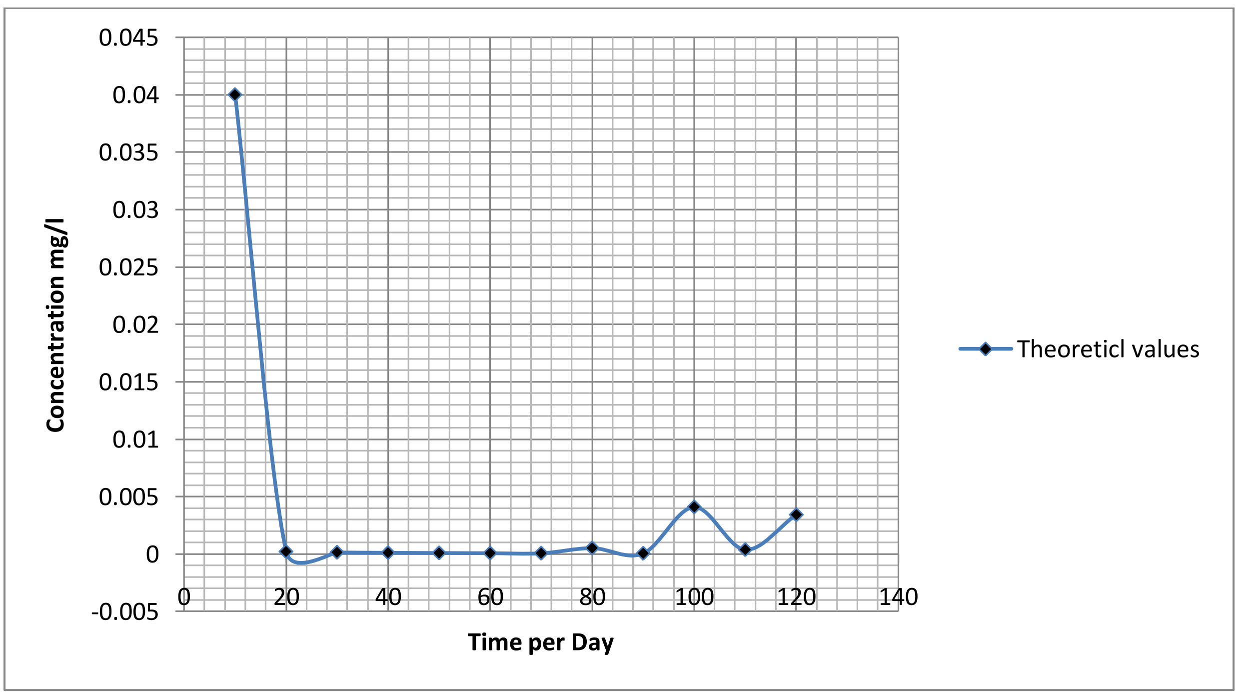


Fig. 5. Theoretical and values at various times.

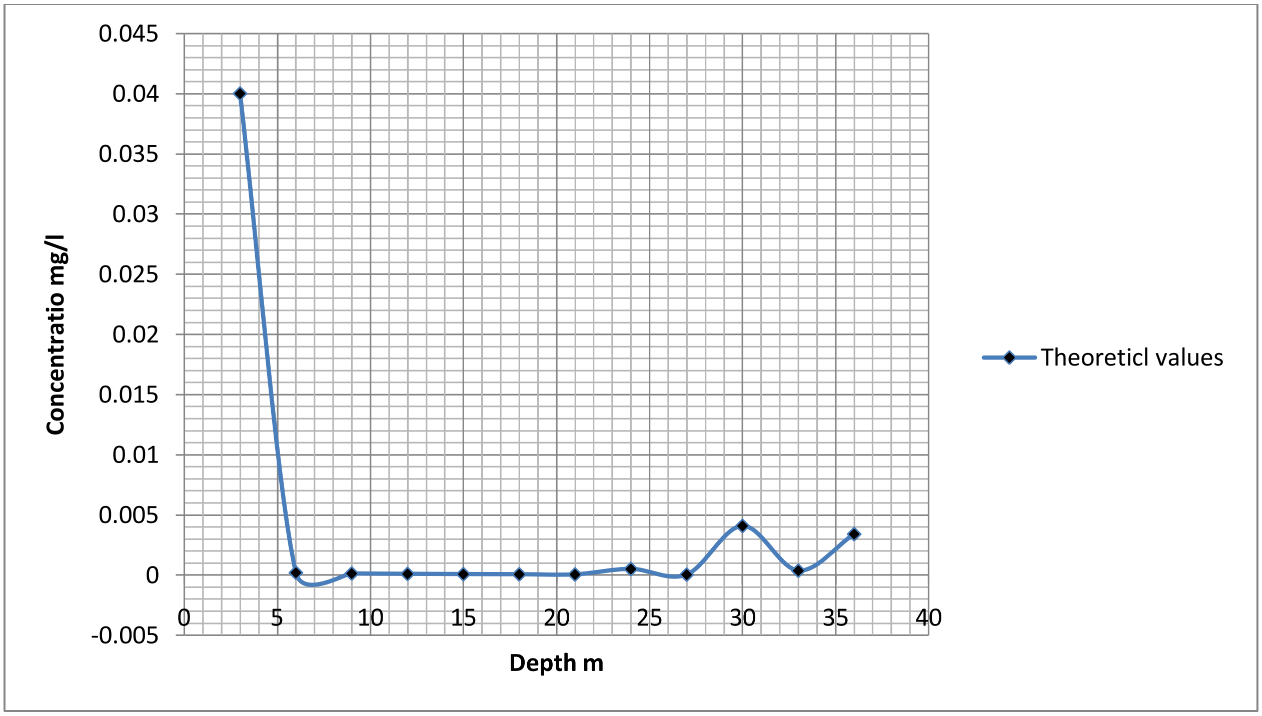


Fig. 6. Theoretical and values at various times.

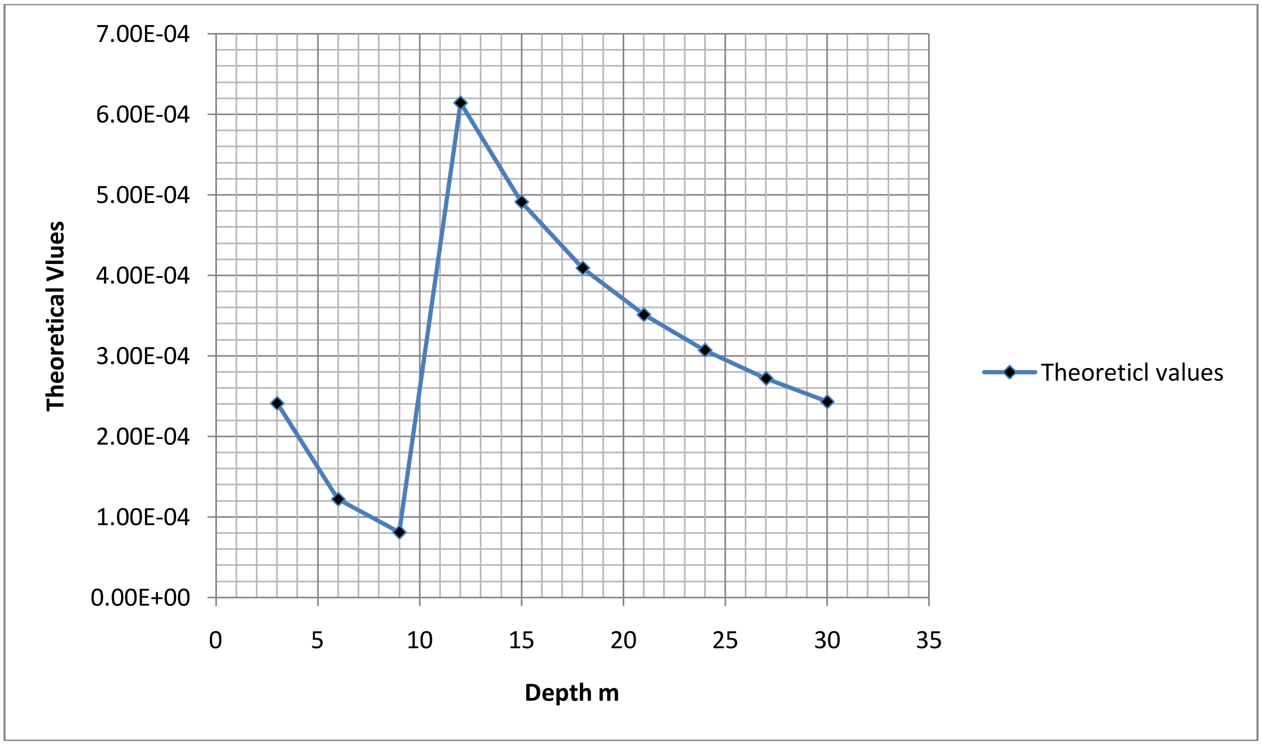


Fig. 7. Theoretical and values at various times.

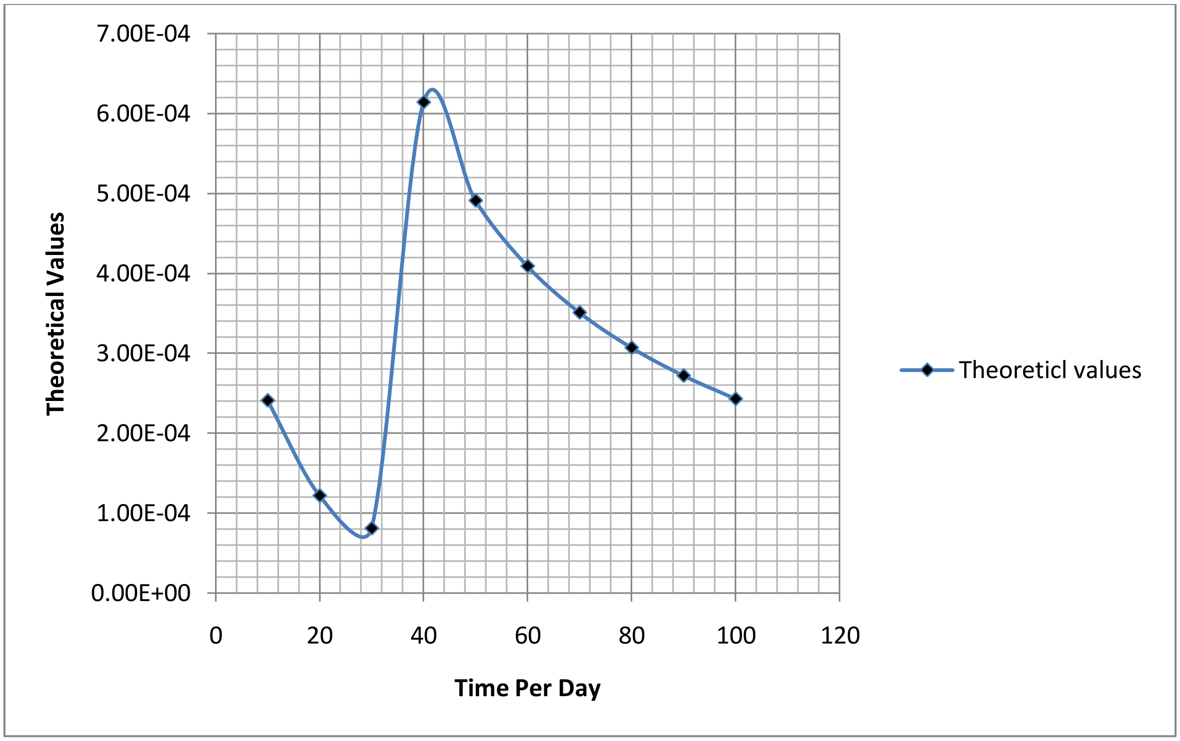


Fig. 8. Theoretical and values at various times.

Figure one experience the physical process from high to low concentration, initial concentration where observed at there meter and ten days. Sudden decrease in concentration where observed, because it has experience change in concentration as the transport process continued, these migration experience linear migration to ground water aquifer but sight increase where observed at hundred days and thirty meters deep. Figure 2 experienced rapid migration and obtained it optimum value at twenty days and suddenly decrease gradually from thirty to hundred days, the reduction in concentration can be attributed to the rate of soil stratification and other inhibitors. The condition found in figure three four and five where the optimum values were found at six meter, sudden decrease from nine to thirty meters where experienced, the figures compared faviourably well with experimental values from other locations The system where found to show it rate of concentration, influenced by the stratification and deltaic nature in the studied area, figure six and seven displayed the rate of concentration at different days and depths showing the rate of inhibition from heavy metal and areas that quality ground water free from enteric virus are found, but the condition of figure eight are not the same like seven and eight, because slight increase where observed between three to nine meters and suddenly experience a rapid increase, where the optimum value were obtained at twelve meters, gradually decrease were observed finally from fifteen to thirty meters, this can attributed to change in concentration at different time and depths as observed from the study, that envic-virus are influenced by the rate of regeneration of the contaminant, as presented from the figures, high degree of inhibition were also confirmed from the study, this implies that there should be thoroughly examination of other contaminants other to develop a concrete design parameter of ground water system in the study area.

4. Conclusion

The transport of entric-virus in ground water environment has been thoroughly assessed, this was done through a development of mathematical model, considering variables that is influential to fast migration of the contaminants in the study area, the model were simulated and the result compared favorable with other experimental values obtained from different location, the result as presented on the figures shows the variation of the dynamic deposition influenced by the geomophological and geochemistry of the soil stratification, this condition has detailed the implication e.g. ground water consumption without thorough analysis and design of ground water system without baseline, this study is imperative because high rate of transportation of microbial pollution can be prevented by applying this developed model in the study locution, the study will assist government of Rivers State and Nigeria out large in ensuring that final solution for entric virus in study area.

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