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Research article

MODELING AND SIMULATION OF THERMOTOLERANT TRANSPORT ON HETEROGENEOUS FINE SAND INFLUENCED BY POROSITY AND PERMEABILITY IN COASTAL AREA OF ABONNEMA

Eluozo, S. N

Subaka Nigeria Limited Port Harcourt Rivers State of Nigeria
Civil and Environmental Engineering consultant, Research and Development
E-mail: solomoneluozo2000@yahoo.com

Abstract

Coastal environment is one of the major study areas in the deltaic environment that has a lot of pollution source in soil and water, developing ground water through water well construction is difficult due to the rate of pollution source either from manmade activities or natural origin. The study area, Abonnema is coastal environmental that is prone to a lot of environmental influence; this condition is a serious issues, when it comes to groundwater abstraction of good quality. To solve this problem a lots of factors from this influence is challenging on the study location, because it is a treat of life. Mathematical model were developed and simulated. Theoretical values were generated from the derived model equation, standard laboratory column and permeability and porosity experiment were carried out, whereby samples of the results were compared with the theoretical values for model validation, both parameters were found to compare favourably well. The value of both parameters explain the rate of concentration at various depths and it has also shown the rate of influence at the coastal environment of Abonnema, the study area were to contain high deposition of porosity and permeability influencing fast migration of Thermotolerant at shallow aquifer, that analysis shows the dynamics of its migration and concentration at various depths. The study is imperative because it has proof the dynamic rate of the concentrate and the stratification of the soil matrix. Finally, it has developed a benchmark for practicing Engineers and Scientists on the need for thorough design and construction of ground water; finally, it has explained the ugly siege on groundwater quality in the coastal environment of Abonnema.

Keywords: water, pollution, environment, Mathematical model

1. Introduction.

The amount and multiplicity of microbial agents that might be present in domestic wastewater is considerable. The routine monitoring for all the possibilities is either not possible or unworkable. The time required to complete most of the analyses precludes their utility as a water quality control feedback tool. The explanation to the dilemma has been the use of indicator bacteria that would be present when potential pathogen containing material (feces) was present. It should be emphasized that the presence of indicator bacteria does not mean the water contains pathogenic microorganisms but rather the potential exists for the existence of pathogens since the indicator bacteria point to the presence of fecal material in the sample. The number of pathogens that might be associated with the concentration of the indicator will be a function of the disease incidence in the community at the time the fecal material was disposed. The ideal indicator should: 1.) be present only when fecal contamination is present; 2.) exhibit the same or greater survival characteristics as the target pathogen for which it is a surrogate; 3.) not reproduce out side of the host; and, 4.) be readily monitored in a timely manner. At the present time no indicators in common use meet all these criteria. The total coliform, fecal coliform and *E. coli* tests have evolved in that order over a period of more than 90 years. The direction of this evolution has been toward a more accurate detection of *E. coli*. This would explain the rather loose accuracy of the total coliform test and the gradual tightening of the measurement as the practice has progressed to the *E. col*i test The coliform assembly includes a number of general and species of bacteria which have common biochemical and morphological attributes that include gram negative, non-spore forming rods that ferment lactose in 24 to 48 hours at 35C. These attributes are found in *Escherichia coli* which are the coliform of most sanitary significance as it is very common in the feces of warm blooded animals. Historically, the coliform test was developed with the aim to estimate the presence of *E. coli* in water samples by detecting bacteria that had the same cultural attributes. As the test was used it soon became clear that it was not specific for *E. coli*. And that a variety of bacteria species can be included under the coliform umbrella, many of which are of limited sanitary significance. The total coliform standard is still used in certain jurisdictions (drinking water for example) as it is felt to be a very conservative risk management tool. Total coliform bacteria that are able to ferment lactose at 44–45 °C are known as Thermotolerant coliforms. In most waters, the predominant genus is *Escherichia*, but some types of *Citrobacter*, *Klebsiella* and *Enterobacter* are also Thermotolerant. *Escherichia coli* can be differentiated from the other Thermotolerant coliforms by the ability to produce in dole from tryptophan or by the production of the enzyme b-glucuronidase. *Escherichia coli* is present in very high numbers in human and animal faeces and is rarely found in the absence of faecal pollution, although there is some evidence for growth in tropical soils. Thermotolerant coliform species other than *E. coli* can include environmental organisms. Indicator value *Escherichia coli* is considered the most suitable index of faecal contamination. In most circumstances, populations of Thermotolerant coliforms are composed predominantly of *E. coli*; as a result, this group is regarded as a less reliable but acceptable index of faecal pollution. *Escherichia coli* (or, alternatively, Thermotolerant coliforms) is the .rst organism of choice in monitoring programmes for verifications, including surveillance of drinking-water quality. (Sueiro et al. 2001) These organisms are also used as disinfection indicators, but testing is far slower and less reliable than direct measurement of disinfectant residual. In addition, *E. coli* is far more sensitive to disinfection than are enteric viruses and protozoa. Source and occurrence *Escherichia coli* occur in high numbers in human and animal faeces, sewage and water subject to recent faecal pollution. Water temperatures and nutrient conditions present in drinking-water distribution systems are highly unlikely to support the growth of these organisms. Application in practice *Escherichia coli* (or, alternatively, Thermotolerant coliforms) are generally measured in 100-ml samples of water. (Ashbolt NJ, Grabow et al 2001) A variety of relatively simple procedures are available based on the production of acid and gas from lactose or the production of the enzyme glucuronidase. The procedures include membrane .alteration followed by incubation of the membranes on selective media at 44–45 °C and counting of colonies after 24 h. Alternative methods include most probable number procedures using tubes or microtitre plates and P/A tests, some for volumes of water larger than 100 ml. Field test kits are available. Significance in drinking-water. The presence of *E. coli* (or, alternatively, Thermotolerant coliforms) provides evidence of recent faecal contamination, and detection should lead to consideration of further action, which could include further sampling and investigation of potential sources such as inadequate treatment or breaches in distribution System integrity. (George et al 2001, Grabow 1996, Grabow 1996). Many option indicators to total coliforms have been proposed including enterococci, sulfite-reducing clostridia, *Bacteroides fragilis,* Bifidobacteria, bacteriophages, and no microbial indicators such as faecal sterols. Of these proposed indicators, enterococcus has gained the most acceptances, particularly when used in conjunction with *E. coli* (Edberg *et al*., 2000; Pinto *et al*., 1999; Sinton *et al*., 1993; WHO, 1993, 1996 1999). A risk management approach for drinking water includes (1) end-point monitoring to verify that the water supplied to consumers was safe; and (2) operational monitoring to show that treatment processes are functioning properly and that distribution system integrity is maintained. End-point monitoring cannot be used as a system control measure, only as a final verification step in a complete risk management plan. Operational monitoring is a means of assessing system performance and results are used to modify system controls to ensure that processes are working within specification. For this reason, on-line and continuous monitoring for operational purposes is better able to support system management. (Payment 1993 and payment, et al 1993). As a component of the assessment of public health risk through monitoring of water quality at consumer's taps, *E. coli* is regarded as the most sensitive indicator of faecal pollution. The large numbers of *E. coli* present in the gut of humans and other warm-blooded animals and the fact that they are not generally present in other environments support their continued use as the most sensitive indicator of faecal pollution available (Edberg *et al*., 2000). To increase the confidence of water quality results, especially when monitoring for faecal pollution, analysis for enterococci has been used. The enterococci are the group of bacteria most often suggested as alternatives to coliforms, and interest in their use as a water quality indicator date back to 1900 when they were found to be common commensal bacteria in the gut of warm-blooded animals (Gleeson and Gray, 1997). The enterococci were included in the functional group of bacteria known as "faecal streptococci" and now largely belong in the genus *Enterococcus* which was formed by the splitting of *Streptococcus faecalis* and *Streptococcus faecium*, along with less important streptococci, from the genus *Streptococcus* (Schleifer and Kreig, 1984). There are now 19 species that are included as enterococci (Topley, 1997). The predominant intestinal enterococci are *Enterococcus faecalis*, *E. faecium*, *E. durans* and *E. hirae*. In addition, other *Enterococcus* species and some species of *Streptococcus* (namely *S. bovis*, and *S. equinus*) may occasionally be detected. Generally, for water examination purposes enterococci can be regarded as indicators of faecal pollution, although some can occasionally originate from other habitats.

2. Materials and Method

Column experiments were also performed using soil samples from forty (6) different borehole locations, the soil samples were collected at intervals of three metres each (3m). An Thermotolerant solute was introduced at the top of the column and effluents from the lower end of the column were collected and analyzed for Thermotolerant and the effluent at the down of the column were collected at different days, analysis, velocity of the transport were monitored at different days. Finally, the results were collected to be compared with the theoretical values. Standard experiment were also carried for porosity while permeability experiment were application failing head method, the analysis results were for model validation.

Developed Mathematical Model

$$K C_{(x)} \frac{\partial V_{(x)}}{\partial t} = \frac{V \partial C_{(x)}}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\frac{V \partial C_{(x)}}{\partial t} = K C_{(x)} \frac{\partial V_{(x)}}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\frac{V \partial C_{(x)}}{\partial t} = -K C_{(x)} \frac{V_x}{t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$\left(\frac{V}{V_x}\right) \frac{\partial C_{(x)}}{\partial (x)} = -\frac{Kdt}{t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$V/V = \int 1/C_{(x)} \; \partial C_{(x)} = -K \int \frac{\partial t}{t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$V/V_{(x)} \left[\ln C_{(x)} = -K \ln \frac{t_o}{t} \right] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

$$\ln \frac{C_{(x)}}{C_{(x)_o}} = -K \frac{V_{(x)}}{V} \ln \frac{t}{t_o} = \ln \left(\frac{t}{t_o} \right)^{-KV_x/V}$$ ……….…………………… (7)

$$\frac{C_{(x)}}{C_{(x)_o}} = \left(\frac{t}{t_o} \right)^{-KV_x/V}$$ …………………………………… (8)

$$\frac{C_{(x)}}{C_{(x)_o}} = \ell^{-K \ln\left(t/t_o \right) V_x/V}$$ …………………………………… (9)

$$C_{(x)} = C_{(x)_o} \ell^{-K \ln 1/t \, V_x/V}$$ …………………………………… (10)

$$C_{(x)} = \beta \ell^{-K \ln 1/t} \, Vx/V$$ …………………………………… (11)

$$\boxed{\beta = C_{(x)_o} \ell^{V_x/tv}}$$ …………………………………… (12)

The model can be applied to resolve the migration of E. coli influence on porosity and permeability.

Integrating both parameters into the equation will yield

$$C_{(x)} = \beta \ell^{-KnVt}$$ …………………………………… (13)

Applying Laplace transform on (13) so that we have

$$C_{(o)} = \frac{\beta}{KnV + S}$$ …………………………………… (14)

=> $$C_{(o)} \left[KnV + S \right] = \beta$$

i.e. $$C_{(o)} KnV + C_{(o)} S - \beta = 0$$ …………………………………… (15)

we can use quadratic formula on (16) so that we can have;

$$C_{(x)} = \frac{-S \pm \sqrt{S^2 + 4\beta KnV}}{2KnV}$$ …………………………………… (16)

With $S = K\,nV$, equation (16) can be expressed as

$$C_{(x)} = \frac{-KnV \pm \sqrt{(KnV)^2 + 4\beta KnV}}{2KnV} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

Now the general solution is

$$C_{(x)} = A\exp\left[\frac{-KnV + \left(K^2n^2V^2 + 4\beta KnV\right)^{1/2}}{2KnV}\right]t + \beta\exp\left[\frac{-KnV - \left(K^2n^2V^2 + 4\beta KnV\right)^{1/2}}{2KnV}\right]t \quad .(18)$$

Subjecting equation (18) to the following conditions:

$x = 0$, $C_{(o)} = 0$ and $t = 0$, so that (18) gives a particular solution of the form

$$C_{(x)} = \exp\left[\frac{-KnV + \left(K^2n^2V^2 + 4\beta KnV\right)^{1/2}}{2KnV}\right]t - \exp\left[\frac{-KnV - \left(K^2n^2V^2 + 4\beta KnV\right)^{1/2}}{2KnV}\right]t \quad . (19)$$

Using the expression $2Sin\,x = \ell^{x} - \ell^{-x}$, our equation (7) yield the result:

$$\boxed{C_{(x)} = 2\,Sin\left[\frac{KnV + \left(K^2n^2V^2 + 4\beta KnV\right)^{1/2}}{2KnV}\right]t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

3. Results and Discussion

Table 1: Theoretical values Thermotolerant concentration at various Depths at constant velocity

Depth m	Constant (V)Theoretical
3	2.82E-09
6	1.14E-08
9	1.75E-08
12	2.29E-08

15	3.10E-08
18	3.82E-08
21	4.10E-08
24	4.56E-08
27	5.35E-07
30	6.11E-08

Table 2: Theoretical values Thermotolerant concentration at various Depths at constant velocity

Depth m	Constant (V)Theoretical
3	3.85E-04
6	5.37E-05
9	8.24E-05
12	1.07E-04
15	1.43E-04
18	1.79E-04
21	1.90E-04
24	2.15E-04
27	2.51E-04
30	2.86E-09

Table 3: Theoretical values Thermotolerant concentration at various Depths at constant velocity

Depth m	Various (V)Theoretical
3	0.57
6	1.34
9	1.59
12	0.015
15	9.53E-03
18	9.18E-03
21	0.04
24	0.026
27	7.19E-03
30	2.50E-02

Table 4: Comparison of Theoretical and Experimental values of Thermotolerant concentration at various Depths at constant velocity

Depth m	Constant (V) Theoretical	Experimental
3	2.82E-09	2.56E-09
6	1.14E-08	3.67E-08

9	1.75E-08	3.21E-08
12	2.29E-08	3.61E-08
15	3.10E-08	2.77E-08
18	3.82E-08	3.66E-08
21	4.10E-08	3.88E-08
24	4.56E-08	3.35E-08
27	5.35E-07	4.69E-07
30	6.11E-08	2.19E-08

Table 5: Comparison of Theoretical and Experimental values of Thermotolerant concentration at various Depths at constant velocity

Depth m	Constant (V)Theoretical	Experimental
3	3.85E-04	4.96E-04
6	5.37E-05	5.14E-05
9	8.24E-05	7.99E-05
12	1.07E-04	1.25E-04
15	1.43E-04	1.97E-04
18	1.79E-04	1.67E-04
21	1.90E-04	1.79E-04
24	2.15E-04	2.23E-04
27	2.51E-04	2.19E-04
30	2.86E-09	2.71E-09

Table 6: Comparison of Theoretical and Experimental values of Thermotolerant concentration at various Depths at constant velocity

Depth m	Various (V)Theoretical	Experimental values
3	0.57	0.54
6	1.34	1.36
9	1.59	1.62
12	0.015	0.018
15	9.53E-03	8.45E-04
18	9.18E-03	8.96E-04
21	0.04	0.05
24	0.026	0.031
27	7.19E-03	7.45E-04
30	2.50E-02	2.66E-03

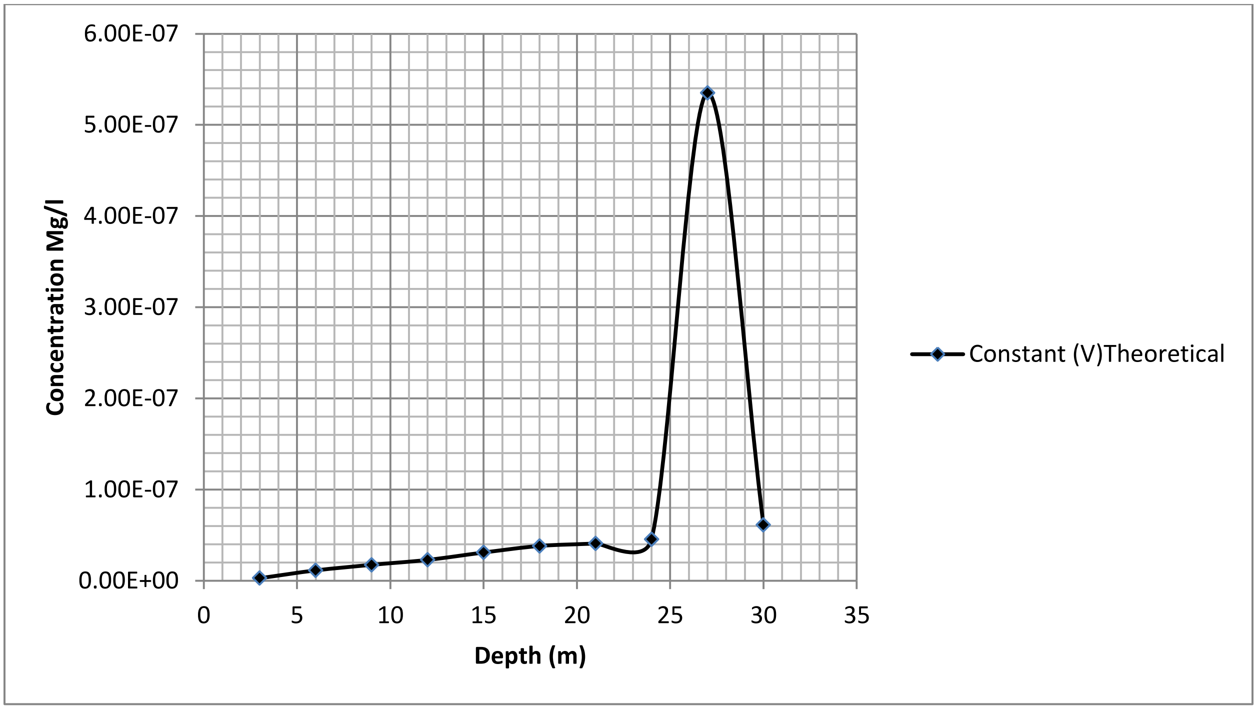

Figure 1: Theoretical values Thermotolerant concentration at various Depths at constant velocity

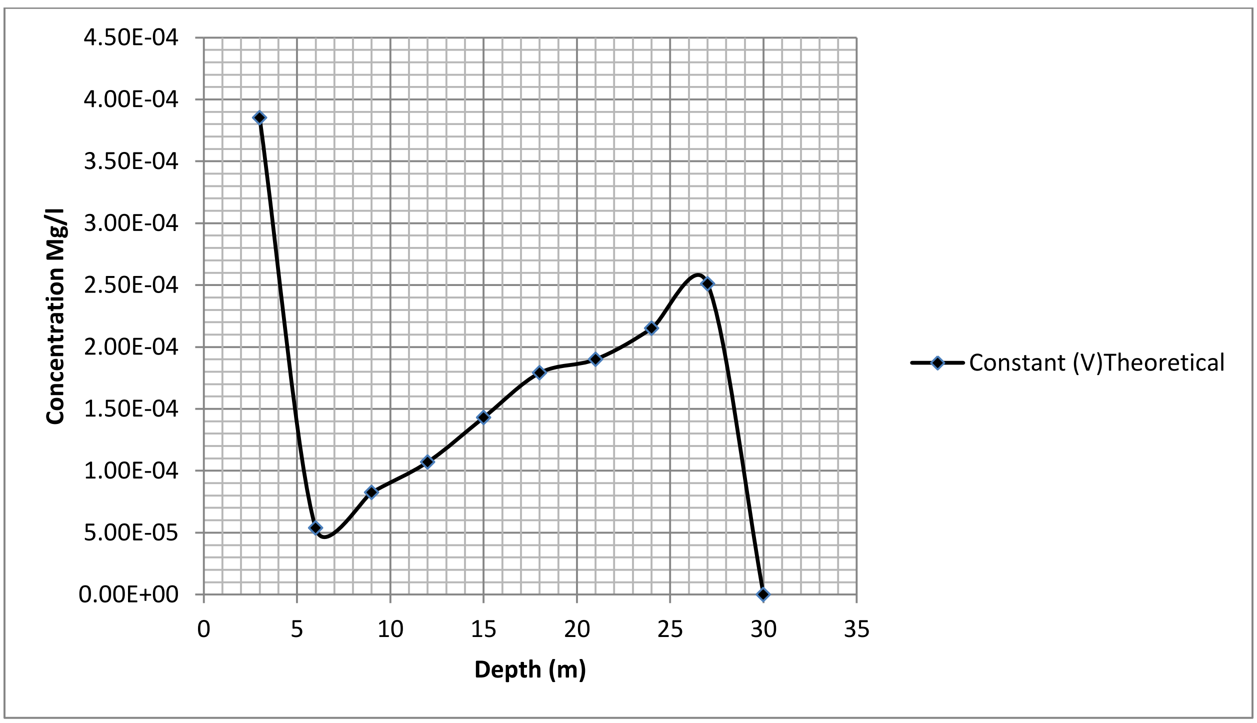

Figure 2: Theoretical values Thermotolerant concentration at various Depths at constant velocity

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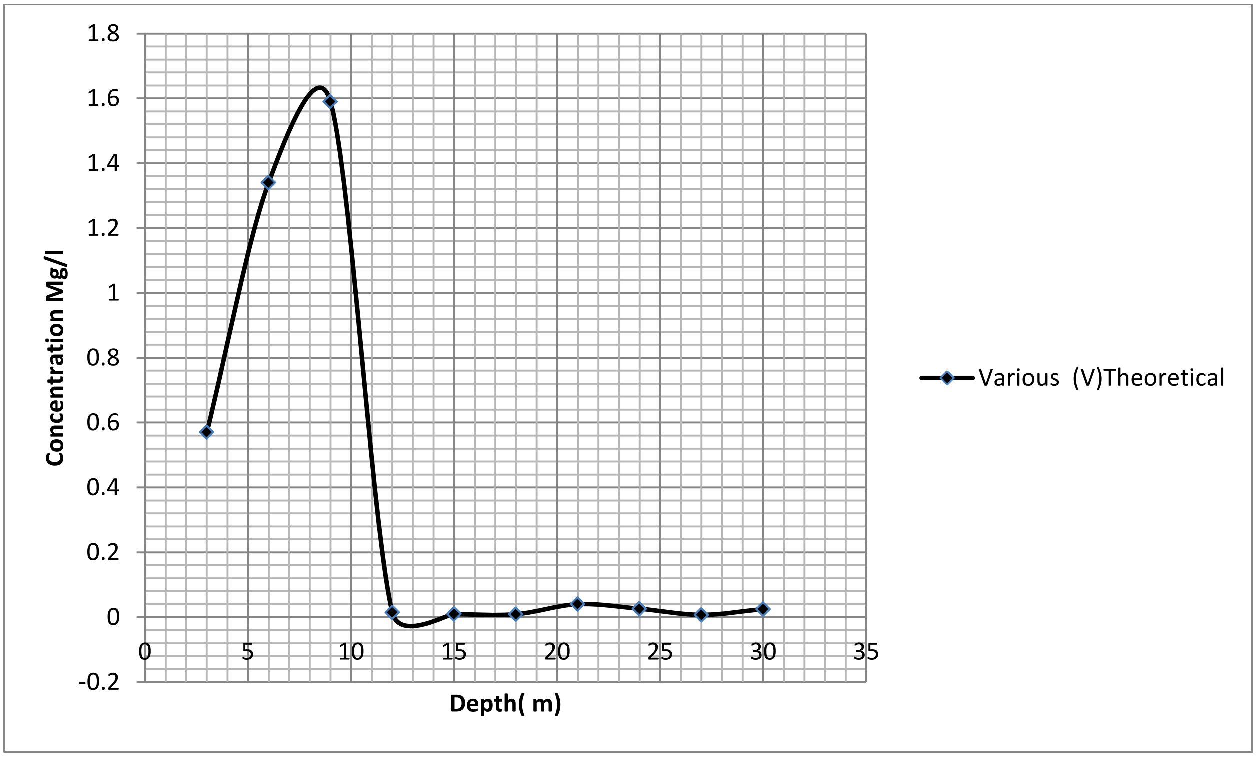

Figure 3: Theoretical values Thermotolerant concentration at various Depths at constant velocity

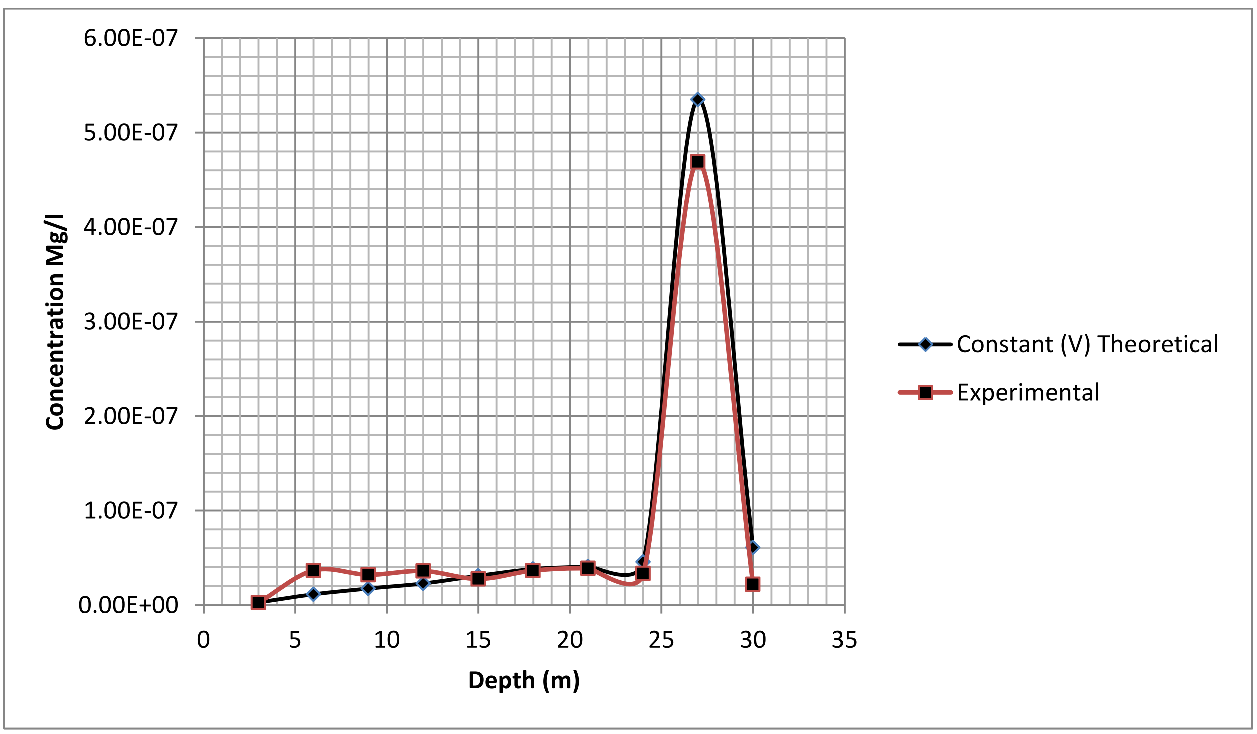

Figure 4: Comparison of Theoretical and Experimental values of Thermotolerant concentration at various Depths at constant velocity

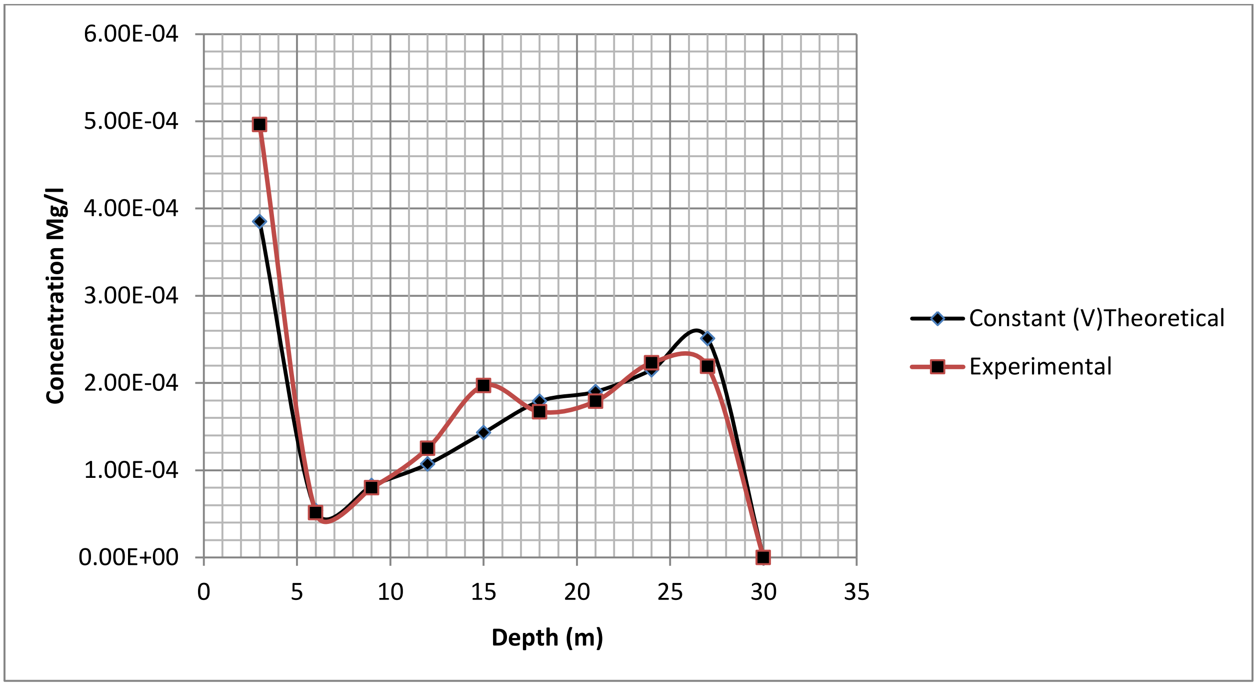

Figure 5: Comparison of Theoretical and Experimental values of Thermotolerant concentration at various Depths at constant velocity

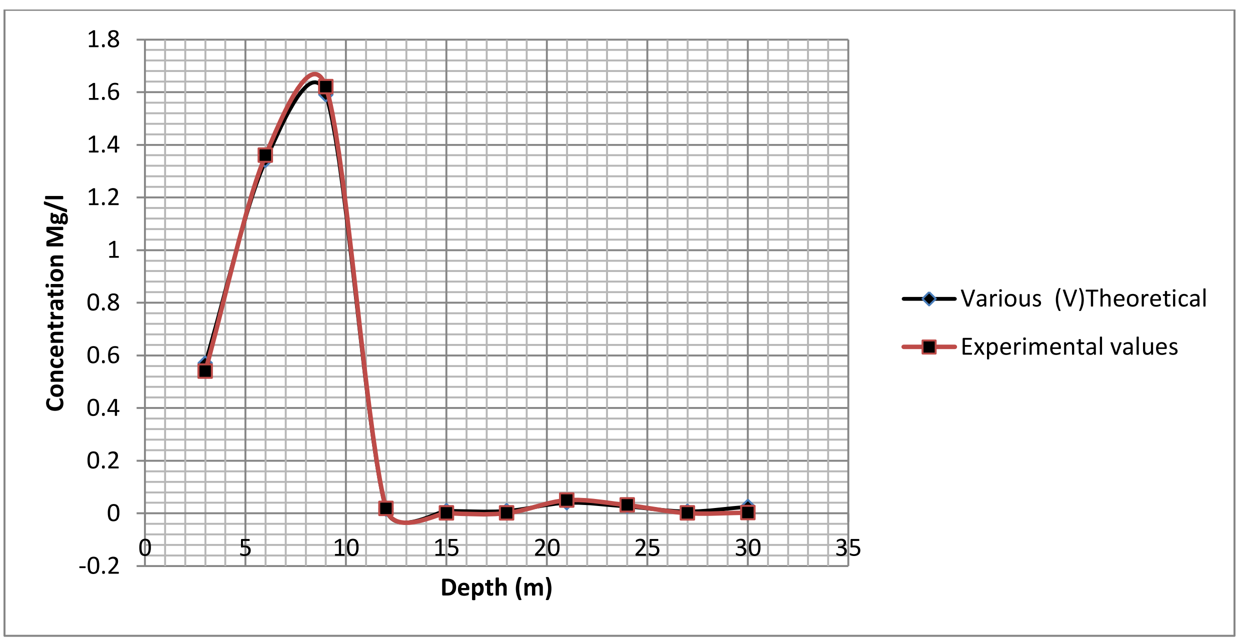

Figure 6: Comparison of Theoretical and Experimental values of Thermotolerant concentration at various Depths at constant velocity

Figure 1 show that the microbes gradually increase from three metres to seventy metres where a rapid increase were observed at ninety metres and suddenly decreased down to hundred metres, while figure 2 expressed a sudden increase at three metres, but experience fluctuation from six metres to thirty metres where the lowest levels of concentration were recorded. Figure 3 experience increases at a certain region but later experience a suddenly decrease fluctuating down to the lowest level of concentration at thirty metres, while figure 4 theoretical values were found to be integrating in an oscillation form and suddenly increased at seventy metres. The experimental maintained the same condition and at hundred metres, both parameters experienced the lowest concentration. Figure 5 both the theoretical and experimental values were found to be fluctuating, the optimum was observed at three metres and the lowest at thirty metres. Figure 6 observed a sudden increase at three metres where the optimum values were recorded, and finally experienced a sudden decrease, both parameters fluctuating down from twelve metres to thirty metres. These models were compared with the experimental values, and it compared favourably well.

Simulation of the model produced the theoretical values, the result from the values compared with the experimental values validates the model, the model can be applied to develop quality drinking water, it has also determined the rate of transport at various depths. The model has developed a design concept for the coastal environment of Abonnema because the geological history of the environment has lots of soil structural dynamics in every deposition due to lots of environmental influence of natural origin. The analytical model developed will definitely serve as a benchmark to monitor the Thermotolerant migration considering these factors in order to produce a better result in groundwater abstraction in the study area.

4. Conclusion

Mathematical modeling of Thermotolerant transport on heterogeneous fine sand influenced by porosity and permeability in coastal area of Abonnema has been carried out. The rates of heterogeneity of the fine sand deposition were observed to have a lot of influence that generate lots of pollution from different sources. These studies consider those factors that contribute to the migration of microbes Thermotolerant migration to aquiferous zone in the coastal environment. The developed model considering these factors, were simulated and that generated theoretical values, standard physicochemical analysis including column experiment were done to determine the rate of concentration at various depths. The experimental value where compared wit6h the theoretical values for validation, both parameters proof to have a fitness, this were done to verify the model authenticity of the model. The values from both parameters shows that rapid increase in some conditions between three to twelve metres, the gradual increase between six metres to twenty-four metres and the degradation between seventy and thirty metres, so fluctuation are influenced by the formation characteristic of the study area. More so, it also included the environmental influence of natural origin and manmade activities from oil exploration and spillage in the coastal environment. It recommended that the abstraction of groundwater should follow the standard required from stipulated studies to develop standard ground water for the communities, the study should treat water even if the construction of the groundwater done through due top future intrusion of pollution of microbes.

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