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Research article

MATHEMATICAL MODEL ON INVERSE MIGRATION OF ENTEROMOBACTER IN HOMOGENEOUS COARSE SAND COLUMN IN COASTAL AREA OF PORT HARCOURT, NIGER DELTA ENVIRONMENT

Eluozo, S. N.

Subaka Nigeria Limited, Port Harcourt, Rivers State of Nigeria
Director and Principal Consultant, Civil and Environmental Engineering, Research and Development
E-mail: Soloeluozo2013@hotmail.com
E-mail: solomoneluozo2000@yahoo.com

Abstract

Mathematical model on inverse migration of enteromobacter in homogeneous coarse sand column has been evaluated. The model was to prevent health hazard by polluted ground water from enteromobacter causing high percent of illness in the study area. This type of menace has caused different diseases generating increase in death rate. Fast migrations of enteromobacter are caused by the deltaic nature of the formation, under the influence of formation characteristics from the geological formation in the study area. Mathematical models were developed to monitor inverse migration of enteromobacter influenced by porosity and permeability from the lithology of the formation. The models were developed in phases considering the variables and their functionalities are expressed in the system. These models were coupled through integration and it generated a final model expression to monitor the rate of inverse migration of enteromobacter in the study location. The study is imperative because experts on this area will be guided by these models to determine the rate of inverse migration of enteromobacter in homogenous coarse sand formation.

Keywords: Mathematical model inverse migration, enteromobacter and homogeneous coarse sand

1. Introduction

This travel time was assumed to cause sufficient die off of pathogenic bacteria from contamination sources (Knorr, 1937). In the past decades, however, viruses, and more recently protozoa like *Cryptosporidium* and *Giardia*, have been recognized as pathogens of major concern in the water industry (Craun *et al*., 1997; MacKenzie *et al*., 1994; Gerba *et al*., 1990). These organisms have been related to waterborne diseases because of their persistence in the

environment, resistance to water treatment, and high infectivity. These organisms are different from bacteria in survival, surface properties, and size. Moreover, it has become clear that die off in groundwater is not the only process that governs the transport of microorganisms. For viruses it was demonstrated that attachment to soil particles was more important than survival in the groundwater (Schijven, 2001). Therefore, viruses and maybe protozoa could be transported over longer distances in soil and thus be more significant to the microbial safety of groundwater number of field studies have been carried out that established either removal of indigenous micro-organisms or lab-cultured seeded microorganisms (Schijven *et al*. 1999, 2000, 2001; Van Olphen *et al*., 1993; Medema and Stuyvesant, 2002). These studies showed that soil passage poses a very effective barrier to micro-organisms, but critical situations may arise (Medema and Stuyfzand, 2002). Such situations are intrusion of contaminations to unconfined aquifers above groundwater wells, water abstraction during RBF from a gravel aquifer, with increased risk during high flow events, or short circuiting during recollection in AR systems. Field studies are valuable but hampered by some drawbacks. The concentration of pathogens in the field is generally too low to assess removal, and only non hazardous model micro-organisms (*Escherichia coli*, bacteriophage, and spores of clostridia) can be used in spiking studies (Schijven *et al*., 2000)..

The importance of attachment and the surface properties of bacteriophage, bacteria, and soil and of water quality parameters has been elucidated by column experiments (Burge and Enkiri, 1978; Sobsey *et al*., 1980; Bales *et al*., 1991; Jin *et al*., 1997; Goldschmid *et al*., 1972; Fletcher and Marshall, 1982; Scholl *et al*., 1990; McCaulou *et al*., 1994). More recently, transport of the oocysts of *Cryptosporidium* in soil columns was studied (Harter *et al*., 2001; Logan *et al*., 2001; Bradford and Bettahar, 2005; Tufenkji *et al*., 2004a), and results indicate the importance of straining on the removal of these larger organisms. The significance of column studies increases when results are related to field conditions of the selected soils and validated by field studies, as described for phage MS2 in dune sand by Schijven (2001).

Soil water regime is highly affected by soil structure and its stability. Various soil structure types may cause preferential flow or water immobilization (Kodešová *et al.,* 2006, 2007, 2008). Soil structure breakdown may initiate a soil particle migration, formation of less permeable or even impermeable layers and consequently decreased water fluxes within the soil profile (Kodešová *et al.,* 2009a). Soil aggregation is under control of different mechanisms in different soil types and horizons (Kodešová *et al.,* 2009b). Soil structure and consequently soil hydraulic properties of tilled soil varied in space and time (Strudley *et al.*, 2008). The temporal variability of the soil aggregate stability was shown for instance by Chan *et al.* (1994), and Yang and Wander (1998). While Chan *et al*. (1994) documented that temporal changes of aggregate stability were not positively related to living root length density; Yang and Wander (1998) suggested that the higher aggregate stability was found due to crop roots, exudates microbial by-products and wet/dry cycles. The temporal variability of the soil hydraulic properties (mainly hydraulic conductivities, *K*) were investigated for instance in following studies. Murphy *et al*. (1993) showed that *K* values at tensions of 10 and 40 mm varied temporally due to the tillage, wetting/drying, and plant growth. Messing and Jarvis (1993) presented that the *K* values decreased during the growing season due to the structural breakdown by rain and surface sealing. Somaratne and Smettem (1993) documented that while the *K* values at tension of 20 mm

were reduced due to the raindrop impact, the *K* values at tension of 40 mm were not influenced. Angulo-Jaramillo *et al*. (1997) discovered that only the more homogeneous sandy soil under furrow irrigation exhibited significant decrease in sorptivity. Petersen *et al*. (1997) documented using the dye tracer experiment that cultivation reduced the number of active preferential flow paths. Azevedo *et al*. (1998) measured tension infiltration from 0 to 90 mm and showed that macropore flow decreased from 69% in July to 44% in September. Bodner *et al.* (2008) discussed the impact of the rainfall intensity, soil drying and frost on the seasonal changes of soil hydraulic properties in the structure-related range. Finally, Suwardji and Eberbach (1998) studied both, aggregate stability and hydraulic conductivities. They documented the lowest aggregate stability during the winter and increased in spring. The *K* values decreased during the growing season. The goal of this study is to assess the seasonal variability of the soil structure, aggregate stability and hydraulic properties with respect to each other and to varying soil physical and chemical properties, soil management and climatic conditions.Veronika et al 2010.

2. Theoretical background

Indiscriminate discarding of wastes is a topic for surroundings concern; this has developed very significant and is troubling public health category in our environment. Steady discarding of these wastes resulted to buildup of entomobacter, consequently lots of contamination are deposited in soil and water environment. The study is in coastal area of Port Harcourt this type of difficulty has consequently generated serious contaminant of organic soil transport in homogeneous fine sand formations in the study area. The leaching of this contaminant is through strata depositions based on geological formation in the coastal area of Port Harcourt, such high inhabited environment produce thousands of metric tons of biological wastes that contain entomobacter migrating through the micropores of the soil down to groundwater aquifers.

The focus of this study is on Concentration of entomobacter, Fraction of equilibrium sorption site, Deposition coefficient, Coefficient of mass transfer, Bacterial concentration on kinetic adsorption, are with respect to time and distance. These microbes Migrates to very vast areas in soil and water environment. To monitor homogeneous coarse fine sand is through water flow and are determined by different sources, at different phases, mathematical equations were formulated through the considered parameters that are variables in the system. These variables are the influential migration of pathogenic bacteria from organic soil to groundwater aquifer. The derived mathematical equations were developed; the model is to monitor soil variance in entomobacter as stated, through the governing equations stated below.

$$\beta \frac{\partial C}{\partial T} = \frac{1}{Pe} \frac{\partial^2 C}{\partial Z^2} - \frac{\partial C}{\partial Z} - w(C - S) \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

Applying physical splitting techniques on equation (1) we have

the governing equation, are derived through the application of physical splitting techniques, this by splitting the variables in accordance with the behaviour of the system, these applications are imperative because the functionality of the variables will be visibly as stated as their functions expressed bellow

3. Nomenclature

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Dimensionless Equation Parameters

C	=	Concentration of entomobacter
β	=	Fraction of equilibrium sorption site
μ	=	Deposition coefficient
T	=	Time
Z	=	Distance
w	=	Coefficient of mass transfer
S	=	Bacterial concentration on kinetic adsorption

$$B\frac{\partial^2 C_1}{\partial T} = \frac{1}{Pe}\frac{\partial^2 C_1}{\partial Z} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\left.\begin{array}{l} x = 0 \\ t = 0 \\ C_{(o)} = 0 \\ \left.\dfrac{\partial C_1}{\partial Z}\right| = 0 \quad x = 0 \quad t = 0 \end{array}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$\beta\frac{\partial C_2}{\partial T} = \frac{\partial C}{\partial Z} - w\,C - S \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$\left.\begin{array}{l} t = 0 \\ x = 0 \\ C_{(o)} = 0 \\ \left.\dfrac{\partial C_2}{\partial T}\right| \quad t = 0,\ \beta \end{array}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$\frac{1}{Pe}\frac{\partial^2 C_3}{\partial Z^2} = -\frac{\partial C_3}{\partial Z} - w\,C - S \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

$$\left.\begin{array}{l} x = 0 \\ C_{(o)} = 0 \end{array}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Applying direct integration on (2)

$$\beta \frac{\partial C}{\partial T} = \frac{1}{Pe} C + K_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

Using physical splitting techniques generated numerous equations that articulated the behaviour of the microorganisms at various phases, this by considering different formations and inverse conditions influenced by advection dispersion, thus hydrodynamic dispersions on the migration of the microbes at various strata in the study location. Such behaviour of the bacteria is expressed at different splited equations through the boundary conditions from equations (2) to (8).

Again, integrate equation (8) directly, yields

$$\beta = \frac{1}{Pe} CZ + K_1 z + K_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

Subject to equation (3), we have

$$BCo = K_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

And subjecting equation (8) to (3)

$$\text{At} \quad \frac{\partial C_1}{\partial Z} \Bigg| \begin{array}{l} = 0 \\ x = 0,\ C_{(o)} = C_o \end{array}$$

Yield

$$0 = \frac{1}{Pe} C_o + K_2$$

$$\Rightarrow \quad K_1 = \frac{1}{Pe} C_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

So that, we put (10) and (11) into (9), we have

$$\beta C_1 = \frac{1}{Pe} C_1 z - \frac{1}{Pe} C_o z + \beta C_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

$$\beta C_1 = \frac{1}{Pe} C_1 z = \beta C_o - \frac{1}{Pe} C_o z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

$$\Rightarrow \quad C_1 \left(\beta - \frac{1}{Pez} \right) = C_o \left(\beta - \frac{1}{Pez} \right)$$

$$\Rightarrow \quad C_1 = C_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

Hence equation (14), entails that at any given distance, x, we have constant concentration of the contaminant in the system

The splited equations derived equation in (2) displayed the parameters by generating constants that were integrated mathematically, this to determine the functionalities through the boundary conditions, the boundary values expressed the limits as derived from equations (10) to (14) where a constant concentration were developed. More so,

the expression implies that the pollutants from coarse sand down to other strata are determined by the formation characteristics, this generated constant flows which influence constant concentration.

$$\beta \frac{\partial C_2}{\partial T} = \frac{\partial C_2}{\partial Z} - w \bullet C - S \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

We approach this system by using the Bernoulli's method of separation of variables

$$C_2 - ZT \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

$$\frac{\partial C_2}{\partial T} = ZT^1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

$$\frac{\partial C_2}{\partial Z} = Z^1 T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

Put (16) and (17) into (15), so that we have

$$\beta XT^1 = w \bullet C - S \; X^1 T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

i.e. $$\beta \frac{T^1}{T} = w \bullet C - S \frac{X^1}{X} = -\lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

Hence $$\beta \frac{T^1}{T} + \lambda^2 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

That is,

$$\frac{X^1 + \lambda}{\beta} X = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

$$w \bullet C - S \; X^1 + \lambda^2 T = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

From (21), $$X = \frac{A Cos \lambda}{\sqrt{\beta}} t + \frac{B Sin \lambda}{\sqrt{\beta}} X \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

And (16) gives

$$\boxed{T = C \ell^{\frac{-\lambda^2}{W \bullet C - S} t}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

The system at this level are found to in a progressive phase, this by discretizing the variables through the application of Bernoulli's method of separation of variable, detail functions of the parameters are expressed on the system , this are in a condition that entomobacter are in progressive phase transporting from various soil formations. From equations (17) to (26) it resulted to a model that expressed the progressive phase of entomobacter with respect to time. These conditions implies that the transport processes were considered on the progressive phase

condition of the entomobacter to determine the rate of concentration at various formations migrating to ground water aquifers.

By substituting (23) and (24) into (15), we get

$$C_2 = \left[A Cos \frac{\lambda}{\sqrt{\beta}} t + B Sin \frac{\lambda}{\sqrt{\beta}} x \right] C \ell^{\frac{-\lambda}{W \bullet C - S} t} \quad \ldots\ldots\ldots\ldots\ldots \quad (25)$$

subject to this relation relations through the substitution of (24) and (26) into (15) generated a model that correlates the interaction of the variables under exponential conditions of the microbes, this are with respect to time and distance, thus these conditions determine the entomobacter rate of concentration influenced by the formation characteristics between the soil strata and groundwater aquifers.

Subject equation (25) to conditions in (5), so that we have

$$C_o = AC \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (26)$$

Therefore, equation (26) become

$$C_2 = C_o \ell^{\frac{-\lambda^2}{w \bullet C - S} t} \; Cos \frac{\lambda}{\beta} x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (27)$$

Again, at

$$\left. \frac{\partial C_2}{\partial T} \right| \begin{matrix} = 0, \; t = 0 \\ x = 0, \; B \end{matrix}$$

Equation (27) becomes

$$\frac{\partial C_2}{\partial t} = \frac{\lambda^2}{\beta} C_o \ell^{\frac{\lambda}{w \bullet C - S}} \; Sin \frac{\lambda}{\beta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (28)$$

$C_o \frac{\lambda}{\beta} \neq 0$ Considering NKP

Which is the substrate utilization for microbial growth (population), so that

$$0 = -C_o \frac{\lambda}{\beta} Sin \frac{\lambda}{\beta} B \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

$$\Rightarrow \frac{\lambda}{\beta} = \frac{n\pi}{2}, n = 1,2,3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

$$\Rightarrow \lambda = \frac{n\pi\sqrt{\beta}}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (31)$$

So that equation (27) becomes

$$C_2 = C_o \ell^{\frac{-n^2\pi^2\beta}{2w \bullet C-S}t \, Cos\frac{n\pi\sqrt{\beta}}{2\sqrt{\beta}}x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (32)$$

$$\therefore \Rightarrow C_2 = C_o \ell^{\frac{-n^2\pi^2\beta}{2w \bullet C-S}t \, Cos\frac{n\pi\sqrt{\beta}}{2\sqrt{\beta}}x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (33)$$

Now, we consider equation (6) which is the steady-flow state of the system

$$\frac{1}{Pe}\frac{\partial^2 C_3}{\partial x^2} = -\frac{\partial C_3}{\partial Z} - w \bullet C - S$$

Applying Bernoulli's method, we have

$$C_3 = ZT \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (34)$$

$$\frac{\partial^2 C_3}{\partial Z^2} = Z^{11}T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (35$$

$$\frac{\partial C_3}{\partial Z} = Z^{1}T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (36)$$

Put (35) and (36) into (6), so that we have

$$\frac{1}{Pe}Z^{11}T = -w \bullet C - S\, X^{1}T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (37)$$

That is,

$$\frac{1}{Pe}\frac{Z^{11}}{Z} = -w \bullet C - S\frac{Z^{1}}{Z} = \varphi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (38)$$

$$\frac{1}{Pe}\frac{Z^{11}}{Z} = \varphi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (39)$$

$$-w \bullet C - S\frac{Z^{1}}{Z} = \varphi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (40)$$

That is $Z = A\ell^{\frac{\varphi}{\frac{1}{Pe}}Z}$ $\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ (41)

And

$$T = B\ell^{\frac{\varphi}{\frac{1}{Pe}}t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (42)$$

The model in this phase are express from equation (42) through the variables developed an interactive expression between other parameters that influences the behaviour of entomobacter under the influence of formation variables, this condition subjects the bacteria on exponential phase in the system. The growth rate of entomobacter is through manmade or natural origin, the deposition of (substrate) utilization within the soil formation were considered to express the increase in microbial population, whereby the formation characteristics definitely influence the transport as it is expressed in the model phase of equation (42)

Put (41) and (42) into (34), gives

$$C_3 = A\ell\frac{\varphi}{w \bullet C - S} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (43)$$

$$C_3 = AB\,\ell^{(x-x)\frac{\varphi}{w \bullet C - S}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (44)$$

Subject equation (44) to (7), yield

$$C_3 = (0) = C_o \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (45)$$

So that equation (45), becomes

$$C_3 = C_o\,\ell^{(x-x)\frac{\varphi}{w \bullet C - S}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (46)$$

Now assuming that at the steady state flow, there is no NKP for substrate utilization, our concentration here is zero, so that equation (46) become

Equation (46) displayed the steady state flow of the fluid that shows the quantity of groundwater in the aquifers level, this condition expressed the generated model at the phase from equation (6) to were the parameters entails there function in terms of steady state, this expression implies that there will be a steady state flow of groundwater within the aquifer. Subject to the condition of microbial transport, there is tendency of regeneration of the microbes, it will definitely mean that the rate of concentration source may attain a high degree to ground water aquifers, this can be determined in coastal fresh water aquifers that develop a shallow depth. But for deep aquiferous zones that are found in some locations in the study area, there may not be substrates deposition. Other conditions can be determined through the rate of dispersion in unsaturated zones; this may also decrease the microbial population to the barest minimum whereby the bacteria may be influenced by such conditions. Formation characteristics such as velocity of flow may also reduce the concentration of the microbes to the barest minimum, depending if there is no regeneration of the contaminants, the quality of groundwater may be up to standard for human consumption.

Now assuming that at the steady flow, there is no NKP for substrate utilization, our concentration here is zero, so that equation (68) becomes

$$C_3 = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (47)$$

Therefore, solution of the system is of the form

$$C = C_1 + C_2 + C_3 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (48)$$

We now substitute (14), (33) and (47) into (48), so that we have the model

$$C = C_o + C_o \ell^{\frac{-n^2\pi^2\frac{1+fP_bK_d}{\theta}}{2Vd\frac{P_b}{\theta}1+fK_dC-Sk}t} Cos\ \frac{n\pi}{2}x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (49)$$

$$C = C_o 1+ \ell^{\frac{-n^2\pi^2\frac{P_b}{\theta}1+fK_dC-Sk}{2Vd\frac{P_b}{\theta}1-fK_dC-Sk}t} Cos\ \frac{n\pi}{2}x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (50)$$

enteromobacter are considered several phases that influence the system, the soil only considered homogeneous coarse sand, these conditions are expressed in the system through the governing equations, the models were developed at several phases and it expressed various models at different state of microbial behaviour, the model at various phases on the transport system were coupled together to generate the final model that will monitor the rate of inverse migration of entomobacter in homogeneous coarse sand in the study location.

4. Conclusion

Ground water in soil environment is determined through several processes, there are various influences that determine the flow of solute in soil, and these influences depend on the structural deposition of the soil at various locations. Coastal area of Port Harcourt is located within the deltaic environment, the major influences of the deposited formation in the study locations are high degree of porosity, permeability including shallow deposition aquifers in the study area. Such conditions were considered during the development of the system to monitor the rate of enteromobacter in soil, the developed equations integrated the rate of concentration of enteromobacter influenced by other parameters like advection and dispersion in the study location.

These formulated equations were derived in phases, the derived model were expressed based on the parameters considered in that condition of the transport process. Such expressed models in several conditions were coupled together to generate a final model equation that expressed all variables in the system as stated in equation (50). The developed mathematical model is vital because it will determine the rate of water flow, through the migration of the entomobacter, under the influence of high degree of porosity in the study area.

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