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Research article

MODELING SOIL COLUMN WATER FLOW ON HEAT PATHOGENIC BACTERIA INFLUENCED BY ADVECTION AND DISPERSION IN PORT HARCOURT, RIVERS STATE OF NIGERIA

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Abstract

Indiscriminate dumping of wastes has caused a lot of pathogenic bacteria pollution in the study area. Such health hazard has caused different diseases generating increase in death rate. Fast migrations of pathogenic bacterial are caused by the deltaic nature of the formation, under the influence of formation characteristics through the geologic setting. To monitor water flow on soil column at different heat in unsaturated zone, several influences from the soil were considered. These include the migration of pathogenic bacteria under the influence of advection and dispersion through porosity and permeability at high degree in the study area. Mathematical models were developed to monitor the rate of water flow on heat and pathogenic bacteria influenced by the stated parameters. The models were developed in phases considering the variables at where 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 water flow on heat pathogenic thus bacteria influenced by advection and dispersion in the study location. The study is significant because experts on this area will be guided by these models to determine the cause of the spread of pathogenic bacteria in soil and water environment. The model also expressed the rate of heat at various unsaturated zones in the study area.

Keywords: Modeling, water flow, pathogenic bacteria and advection and dispersion.

1. Introduction

There a lots characteristics that affect the survival of pathogens in water, mainly bacteria and viruses, comprise temperature, pH, dissolved oxygen, water hardness, presence of organic material, exposure to sunlight, the existence of other micro-organisms and water conductivity (O'Brien & Newman, 1977; Lund, 1978; Melnick & Gerba, 1980; Davies-Colley et al. 1994). Protozoan cysts live above a wide variety of Ph values and are opposed to to osmotic pressures. *Cryptosporidium* oocysts can survive for over one year in isotonic the solutions are from laboratory; this may remain viable for long time in aquatic environments (Smith et al. 1991). The foremost issue affecting cyst and

also helminth egg survival in water is temperature is the higher temperatures resulting in faster death (Feachem et al. 1983; O'Donohue, 1995). Pathogens are carried through water over quite large distances. In a analysis done in Zambezi River express that the bacteria were still detected 18.6 km downstream from the source of pollution at levels at 1.4 x 103 *E. coli*/100 ml (Feresu & Van Sickle, 1990). Lund (1978) similarly an observations were pressed in tropical waters. Too much quantity of fecal bacteria in surface water, these were found to increases the risk of bacteria−induced illness to humans (Frenzel and Couvillion, 2002). Payment et al. (2000) found that the presence of pathogenic microorganisms (human enteric virus, *Cryptosporidium*, and *Giardia*) deposited Saint Lawrence River in Canada; this was comprehensively correlated with bacterial indicators (total coliform, fecal coliform, and *Clostridium perfringens*). concentration rate of fecal coliform from 200 colony−forming units (cfu) per 100 mL of water was established as a water−quality standard by the Federal Water Pollution Control Administration of the Department of the Interior in 1968 (USEPA, 1986). Current research, however, established that fecal coliforms confound to deposit less correlation to swimming−associated gastroenteritis than the other two common indicator bacteria (*Escherichia coli* and enterococci), prompting a shift in the suggested indicator organisms (USEPA, 1998, 2002).

Total coliform, fecal coliform, fecal streptococci, enterococci, and *E. coli* bacteria are ordinary shows the existence species used to recognize the potential existence of pathogens. Preferably indicators for pathogens exist in much greater concentrations, demonstrate similar die−off and re−growth formations, and are connected with the equivalent sources (Moore et al., 1982). The first indicator used to examine pollution of drinking water by human waste was total coliform. Since exact pathogens are very complicated to collect and culture, the total coliform assembly was initially selected as an indicator because it was easy to detect, easy to culture, and typically is connected with fecal pollution from warm−blooded animals (Larsen et al., 1994). However, total coliforms include several organisms exists in non−fecal sources, making this indicator group too broad to be a steadfast indicator of fecal pathogens (Rosen, 2000). Fecal coliforms are a subgroup of total coliforms that originate specifically from the intestinal tracts of warm− blooded animals. Fecal coliforms are the predominant indicator used to assess human health hazards in streams (Rosen, 2000), but *E. coli* and enterococci are thought to have a higher degree of association with outbreaks of gastrointestinal illness (USEPA, 1986). *E. coli* is a constituent of the fecal coliform group and includes the toxin−producing O157:H7 strain. Enterococci is a subgroup of fecal streptococci that belongs to the genus *Streptococcus* and differs from fecal coliforms in that enterococci are less abundant in feces, are not known to replicate in the environment, and are more resistant to environmental stress (Maier et al., 2000).

Land application of waste from confined animal production facilities is an effective method of disposing of animal waste while supplying nutrients to crops and pastureland. However, it has been well-documented that runoff from agricultural livestock and poultry litter applied areas is a source of fecal contamination in water (Crowther *et al.*, 2002; Edwards *et al.*, 1994, 2000; Gerba and Smith, 2005; Tian *et al.*, 2002). The EPA's National Water Quality Inventory report (USEPA, 2000) identified bacteria as the leading cause of impairments in rivers and streams in the United States and agricultural practices were identified as the leading source of all bacterial impairments Transport of animal manures into surface water bodies can be detrimental to the health of humans, animals, and the ecosystem

(USEPA, 2003). Animal waste contains many different types of organisms pathogenic to humans and animals which could be transported into streams when over-applied to agricultural lands. More than 150 pathogens found in livestock manure are associated with risks to humans, including *Campylobacter spp.*, *Salmonella spp.*, *Listeria monocytogenes*, *Escherichia coli* O157:H7, *Cryptosporidium parvum* and *Giardia lamblia*, which account for over 90% of food and waterborne diseases in humans (USEPA, 2003).

2. Theoretical background

Indiscriminate dumping of wastes is a subject for environment concern; this has generated a lot threats, which has disturbed public health status in our environment. Constant dumping of this wastes result to accumulation of pathogenic bacteria, it has resulted to a lot of pollution in soil and water environment. The study area – Port Harcourt has this type of problem that has resulted to serious contaminant of organic soil transporting to various soil formations in the study area. The leaching of this pollutant is through strata depositions based on geological settings in Port Harcourt metropolis, such high populated environment generate thousands of metric tones of biological wastes that contain pathogenic bacteria thus migrating through the micropores of the soil down to groundwater aquifers.

The focus of this study is on advection and dispersion; the advection dispersion increased the pathogenic bacteria migration to a very vast area in soil and water environment. To monitor this type of soil columns through water flow and determine different sources of heat on pathogenic bacteria, mathematical equations were formulated through the considered parameters that are variables in the system. These variables are the influential parameters that influence the migration of pathogenic bacteria from organic soil to groundwater aquifer. The derived mathematical equations that developed the model is to monitor soil column water flow on temperature variance in pathogenic bacteria as stated, through the governing equations below.

3. Governing Equation

$$\frac{\phi\partial(\theta c)}{\partial t} = \frac{V\partial\theta c}{\partial t}\left(\theta D\frac{\partial c}{\partial z}\right) - \frac{\phi V\partial\theta c}{\partial z} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

From the governing equation, through the application of physical splitting techniques were applied to split the variables in accordance with the behaviour of the system, these applications are imperative because the functionality of the variables will be clearly stated as their functions are expressed in the system.

Applying physical splitting techniques on equation (1) we have

$$\phi\partial\frac{\partial\theta c_1}{\partial t} = V\frac{\partial\theta c_1}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (2)$$

$$\left.\begin{array}{l} t = 0 \\ C_{(o)} = 0 \end{array}\right\} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (3)$$

$$\left.\frac{\partial c_1}{\partial t}\right| \quad t = 0$$

$$\phi\frac{\partial\theta c_2}{\partial t} = \theta\frac{D\partial c_2}{\partial z} \qquad \text{..... (4)}$$

$$\left.\begin{array}{l} t = 0, \\ x = 0 \\ C_{(o)} = 0 \\ \left.\dfrac{\partial c_2}{\partial t}\right| = 0 \\ \qquad t = 0 \end{array}\right\} \qquad \text{..... (5)}$$

$$\frac{\phi\partial\phi c_3}{\partial t} = -\frac{\phi V\partial\phi c_3}{\partial z} \qquad \text{..... (6)}$$

$$\left.\begin{array}{l} t = 0 \\ x = 0 \\ C_{(o)} = 0 \\ \left.\dfrac{\partial c_3}{\partial t}\right| = 0 \\ \qquad t = 0 \end{array}\right\} \qquad \text{..... (7)}$$

$$\frac{\phi D\partial c_4}{\partial z} = -\frac{\phi V\partial\theta c}{\partial z} \qquad \text{..... (8)}$$

$$\left.\begin{array}{l} x = 0 \\ C_{(o)} = 0 \\ \left.\dfrac{\partial c_4}{\partial z}\right| = 0 \\ \qquad x = 0 \end{array}\right\} \qquad \text{..... (9)}$$

The application of physical splitting techniques developed several equations that expressed the behaviour of the microbes at different phases. The study consider different formations and different temperatures influenced by advection dispersion on the migration of the microbes at different strata in the study location. Such behaviour of the bacteria is expressed at different splited equations through the boundary conditions from equations (2) to (9).

Applying direct integration on (2)

$$\frac{\phi\partial\theta c}{\partial t} = \phi V\theta c + K_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

Again, integrate equation (10) directly, yield

$$\phi\theta C = V\theta Ct + K_1 t \quad K_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

$$\phi\theta C = K_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

And subjecting equation (10) to (3), we have

$$At \quad \frac{\partial c_1}{\partial t}\Bigg| \begin{matrix} = 0 \quad C_{(o)} = C_o \\ t = 0 \end{matrix}$$

Yield

$$0 = V\theta C_o + K_2$$

$$\Rightarrow K_2 = -V\theta C_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

So that we put (11) and (12) into (13), we have

$$\phi\theta C_1 = V\theta Ct - V\theta C_o t + \phi\theta C_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

$$\phi\theta C_1 - V\theta C_1 t = \phi\theta C_o - V\theta C_o t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

$$\Rightarrow C_1(\phi\theta - V\theta) = C_o(\phi\theta - V\theta t)$$

$$\Rightarrow C_1 = C_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

Hence equation (16), entails that at any given distance x, we have constant concentration of the contaminant in the system.

From the splited equations, the derivation equation (2) expressed the parameters generating constants that were integrated mathematically, this is to determine the functionality of the boundary conditions which expressed the limits as derived from equations (10) to (16) constant concentration were express, thus the expression implies that the contaminants within the organic soil down to other stratum are determined by the formation characteristics that develop a constant flow which influence constant concentration in the system.

Now, we consider equation (4) which is the progressive phase of the system

$$\phi\frac{\partial\theta c_2}{\partial t} = \theta\frac{D\partial c_2}{\partial z} \quad \ldots\ldots\ldots\ldots \quad (4)$$

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

$$i.e. \quad C_2 = ZT \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

$$\text{i.e.} \quad \frac{\partial c_2}{\partial t} = ZT^1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

$$\frac{\partial c_2}{\partial Z} = Z^1 T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

Put (18) and (19) into (17), so that we have

$$\phi\theta Z T^1 = \phi D Z^1 T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

$$\text{i.e. } \frac{\phi\theta T^1}{T} = \frac{\theta D Z^1}{Z} = -\lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

$$\text{Hence } \frac{\phi\theta T^1}{T} + \lambda^2 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

$$Z^1 + \frac{\lambda^2}{\phi\theta} Z = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

$$And\ \theta D Z^1 + \lambda^2 T = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

$$\text{From (23) } T = ACos\ \frac{\lambda}{\phi\theta} t + B\,Sin\ \frac{\lambda}{\phi\theta} z \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (25)$$

And (19) gives:

$$\boxed{T = C\ell^{\frac{-\lambda^2}{\theta D} t}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (26)$$

The model expressed in the system shows progressive phase, these discretizing the variables through the application of Bernoulli's method of separation of variable, this the expressed details functions of the parameters that expressed the influential parameters of the system on progressive phase, thus pathogenic bacteria migrating at different soil formations. From equations (17) to (26) it resulted to a model that expressed the progressive phase of pathogenic bacteria with respect to time. These conditions imply that the transport processes were considered on the progressive phase condition of the bacteria to determine the system at various formations while migrating to ground water aquifers.

By substituting (24) and (26) into (17) we have

$$\boxed{C_2 = \left[ACos\ \frac{\lambda}{\sqrt{\phi\theta}} t + B\,Sin\ \frac{\lambda}{\sqrt{\phi\theta}} x \right] C\ell^{\frac{-\lambda^2}{\phi\theta} t}} \quad \ldots\ldots\ldots\ldots\ldots \quad (27)$$

Expressing the subject relations through the substitution of (24) and (26) into (17) developed model correlated were there is an enable environment to interact with other variables under exponential conditions. The microbial transport with respect to time and distance are subjected to these conditions, these determine the bacteria rate of concentration influenced by the formation characteristics between the soil strata and groundwater aquifers.

Subject equation (27) to condition in (5), so that we have

$$C_o = AC \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (28)$$

Equation (28) becomes:

$$C_2 = C_o \ell^{\frac{-\lambda^2}{\theta D}t} \, Cos \frac{\lambda}{\sqrt{\phi\theta}} z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

Again at $\left.\frac{\partial c_2}{\partial t}\right| = 0, \quad t = 0$

$$t = 0, B$$

Equation (29), becomes:

$$\frac{\partial c_2}{\partial t} = \frac{\lambda}{\sqrt{\phi\theta}} C_o \ell^{\frac{-\lambda^2}{\theta D}t} \, Sin \frac{\lambda}{\phi\theta} x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

i.e. $0 = -C_o \frac{\lambda}{\sqrt{\phi\theta}} \, Sin \frac{\lambda}{\sqrt{\phi\theta}} 0$

$C_o \frac{\lambda}{\sqrt{\phi\theta}} \neq 0$ Considering NKP

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

$$0 = -C_o \frac{\lambda}{\sqrt{\phi\theta}} \, Sin \frac{\lambda}{\sqrt{\phi\theta}} B \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (31)$$

$$\Rightarrow \frac{\lambda}{\sqrt{\phi\theta}} = \frac{n\pi}{2}, \, n, 1, 2, 3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (32)$$

$$\Rightarrow \lambda = \frac{n\pi\sqrt{\phi\theta}}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (33)$$

So that equation (29) becomes

$$C_2 = C_o \ell^{\frac{-n^2\pi^2\phi\theta}{2\theta D}t} \, Cos \frac{n\pi\sqrt{\phi\theta}}{2\sqrt{\phi\theta}} x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (34)$$

$$\Rightarrow C_2 = C_o \ell^{\frac{-n^2\pi^2\phi\theta}{2\theta D}t} \, Cos \frac{n\pi}{2} x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (35)$$

An expressed model from equation (35) through the boundary condition developed the limit of time, this is to express the pathogenic bacteria behaviour under the influence of formation variables, and this condition subjects the bacteria on exponential phase in the system. The growth rate of the pathogenic bacteria through manmade or natural origin were expressed, the deposition of (substrate) utilization within the soil formation were considered to express the increase in microbial population, whereby the formation characteristics will definitely influence the transport as it is expressed in the model phase of equation (35).

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We consider equation (6)

$$\frac{\phi\partial\phi c_3}{\partial t} = -\frac{\phi V\partial\phi c_3}{\partial z} \qquad \ldots\ldots\ldots\ldots \qquad (6)$$

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

$$C_3 = ZT \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (36)$$

$$\frac{\partial c_3}{\partial t} = ZT^1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (37)$$

$$\frac{\partial c_3}{\partial Z} = Z^1T \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (38)$$

Again, we put (37) and (38) into (36), so that we have

$$\phi\theta ZT^1 = \phi VZ^1T \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (39)$$

i.e. $$\frac{\phi\theta T^1}{T} = \frac{\phi VZ^1}{Z} = -\lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (40)$$

Hence $$\frac{\phi\theta T^1}{T} + \lambda^2 = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (41)$$

i.e. $$Z^1 + \frac{\lambda^2}{\phi\theta}Z = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (42)$$

And $$\phi\theta T^1 + \lambda^2 T = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (43)$$

From (43) $$Z = ACos\frac{\lambda}{\sqrt{\phi\theta}}Z + BSin\frac{\lambda}{\sqrt{\phi\theta}}Z \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (44)$$

$$T = C\ell^{\frac{-\lambda^2}{\phi\theta}t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (45)$$

By substituting (44) and (45) into (36), we get

$$C_3 = \left(ACos\frac{\lambda}{\sqrt{\phi\theta}}Z + BSin\frac{\lambda}{\sqrt{\phi\theta}}Z\right)C\ell^{\frac{-\lambda}{\phi\theta}t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (46)$$

Subject (46) to conditions in (9), so that we have

$$C_o = AC \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (47)$$

$\therefore$ Equation (47) becomes:

$$C_3 = C_o\ell^{\frac{-\lambda^2}{\phi\theta}t}Cos\frac{\lambda}{\sqrt{\phi\theta}}Z \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (48)$$

Again, at $$\left.\frac{\partial c_3}{\partial t}\right|_{t = 0,\, B} = 0, \quad t = 0$$

Equation (48), becomes:

$$\frac{\partial c_3}{\partial t} = \frac{\lambda}{\sqrt{\phi\theta}} C_o \ell^{\frac{-\lambda^2}{\phi\theta}t} Sin\frac{\lambda}{\phi\theta} Z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (49)$$

$$C_o \frac{\lambda}{\sqrt{V}} \neq 0 \quad \text{Considering NKP}$$

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

$$0 = -C_o \frac{\lambda}{\sqrt{\phi\theta}} Sin\frac{\lambda}{\sqrt{\phi\theta}} B \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (50)$$

$$\Rightarrow \frac{\lambda}{\sqrt{\phi\theta}} = \frac{n\pi}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (51)$$

$$\Rightarrow \lambda = \frac{n\pi\sqrt{\phi\theta}}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (52)$$

So that equation (48) becomes

$$C_3 = C_o \ell^{\frac{-n^2\pi^2\phi\theta}{4\phi\theta}t} Cos\frac{n\pi\sqrt{\phi\theta}}{2\sqrt{\phi\theta}} Z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (53)$$

$$\Rightarrow C_3 = C_o \ell^{\frac{-n^2\pi^2\phi\theta}{4\phi\theta}t} Cos\frac{n\pi}{2} Z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (54)$$

Based on variations on formation characteristics, the substrates deposition varies. These depositions are influenced by the geological settings, including the rate of deposition of the substrate. Manmade activities or natural origin has influenced the depositions of the substrates. These conditions were considered since the depositions of the microelements are not homogeneous in the soil formation. Such microbial growth were considered for the second time due to the tendency of regeneration of the substrates on the transport process in soil and water environment as it is expressed in the model in equation (54).

Now, we consider equation (8), which is the steady flow rate of the system

$$\theta D\frac{\partial c_4}{\partial Z} = -\phi V\frac{\partial \theta c}{\partial Z} \quad \ldots\ldots\ldots\ldots \quad (8)$$

Using Bernoulli's method, we have

$$C_4 = ZT \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (55)$$

$$\frac{\partial c_4}{\partial Z} = Z^1T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (56)$$

$$\frac{\partial c_4}{\partial Z} = Z^1T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (57)$$

Put (56) and (57) into (8), so that we have

$$\theta D Z^1 T = -\phi V \theta Z^1 T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (58)$$

i.e. $$\frac{\theta D Z^1}{X} = -\phi V \theta \frac{Z^1}{Z} = \varphi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (59)$$

$$\frac{\theta D Z^1}{X} = \varphi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (60)$$

$$-\phi V \theta \frac{Z^1}{Z} = \varphi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (61)$$

$$Z = A \frac{\varphi}{\theta D} Z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (62)$$

And $$Z = B\ell \frac{-\varphi}{\phi V \theta} Z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (63)$$

Put (62) and (63) into (55), gives

$$C_4 = A\ell^{\frac{\varphi}{\phi V \theta} x} \quad B\ell^{\frac{-\varphi}{\phi V \theta} x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (64)$$

$$C_4 = AB\ell^{(z-z)} \frac{\varphi}{\phi V \theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (65)$$

Subject equation (66) and (67) yield

$$C_{(4)} = (o) = C_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (66)$$

So that, equation (66) becomes

$$C_4 = C_o \ell^{(z-z)} \frac{\varphi}{\phi V \theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (67)$$

Equation (67) entails the steady state flow of the fluid that determines the quantity of groundwater in aquiferous zones, in this condition, the expressed model from equation (8) implies that there will be a steady state flow of groundwater within the aquifer. Subject to the condition, the transport of pathogenic bacterial if there is tendency of regeneration will definitely implies that concentration from this point may attain a high degree, 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. Other conditions can be determined through the rate of temperature in unsaturated zones that may also decrease the microbial population to the barest minimum, whereby pathogenic bacteria may be influenced by such conditions. Formation characteristics such as velocity of flow may also reduce the concentration of pathogenic bacteria to the barest minimum. The quality of groundwater from such formation 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

$$C_4 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (68)$$

In some conditions, due to the variables on the geological setting in the soil formation, the rate of man made or natural origin may be very low, the geological setting may influence the reduction of the substrate or it could not deposit in such formations. It implies that the substrate may be insignificant or never in existence, therefore, the developed model, in equation (68) was expressed as zero. Such condition expresses that the substrate does not exist in the system. In this condition the concentrations are affected.

Therefore solution of the system is of the form

$$C = C_1 + C_2 + C_3 + C_4 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (69)$$

Now, we substitute (16), (35), (54) and (69) into (70), so that we have the model of the form

$$C = C_o + C_o \ell^{\frac{-n^2\pi^2\phi\theta}{2\theta D}t} \bullet {}^{\frac{n^2\pi^2\phi\theta}{4\phi\theta}x} Cos\frac{n^2\pi^2}{4}Z \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (70)$$

The final equation becomes

$$\Rightarrow C = C_o\left[1 + \ell^{\frac{-n^2\pi^2\phi\theta}{4\phi}t} \bullet {}^{\frac{n^2\pi^2\phi\theta}{4\phi\theta}} + Cos\frac{n^2\pi^2}{4}Z\right] \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (71)$$

Pathogenic bacteria are considered in various phases, the soil has unsaturated and saturated zones, these conditions are expressed in the system through the governing equations, the models were developed at various phases and it expressed different models , this is determined from the phases considered under the influence of the 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 column water flow on heat pathogenic bacteria through advection and dispersion in the study location.

4. Conclusion

Water flow in soil environment is determined through various processes, there are several influences that determine the flow of fluid in soil, and these influences are from the deposition of the soil at various locations. Port Harcourt metropolis 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 of ground water aquifers in the study area. Such conditions were considered during the development of the system , this is to monitor the rate of soil column and heat condition in unsaturated zone in soil, the developed equations integrated together the rate of pathogenic bacteria concentration influenced by advection and dispersion in the study location. These formulated equations were derived in phase, the derived model were expressed based on the parameters considered in that condition of transport process. Such expressed models in several conditions were coupled together to generate a final model equation, this express all the variables in the system as stated in equation (71). The developed mathematical model is essential, because it will determine the rate of water flow, thus, the heat in unsaturated and

saturated zones through the migration of pathogenic bacteria, under the influence of advection and dispersion in the study area.

References

[1] Crowther, J., Kay, D. and Wyer, M. D.: 2002, 'Faecal-indicator concentrations in waters draining lowland pastoral catchments in the UK: Relationships with land use and farming practices', *Water Res*. **36**(7), 1725–1734.

[2] Edwards, D. R., Daniel, T. C., Moore, Jr., P. A. and Sharpley, A. N.: 1994, 'Solids transport and erodibility of poultry litter surface-applied to fescue', *Trans ASAE*. **37**(3), 771–776
.
[3] Edwards, D. R., Larson, B. T. and Lim, T. T.: 2000, 'Runoff nutrient and fecal coliform content from cattle manure application to fescue plots', *J. Am. Water Resour. Assoc*. **36**(4), 711–721.

[4] Gerba, C. P. and Smith, J. E.: 2005, 'Sources of pathogenic microorganisms and their fate during land application of wastes', *J. Environ. Qual*. **34**, 42–48.

[5] Tian, Y. Q., Gong, P., Radke, J. D. and Scarborough, J.: 2002, 'Spatial and temporal modeling of microbial contaminants on grazing farmlands', *J. Environ. Qual.* **31**(3), 860–869.

[6] Davies-Colley, R.J., Bell, R.G. and Donnison, A.M., 1994. Sunlight inactivation of enterococci and fecal coliforms in sewage effluent diluted in seawater. Applied and Environmental Microbiology, **60**, 2049-2058.

[7] Feachem, R.G., Bradley, D.J., Garelick, H. and Mara, D.D., 1983. Sanitation and Disease: Health Aspects of Excreta and Wastewater Management. Chichester: John Wiley & Sons.

[8] Feresu, S.B., and Van Sickle, J., 1990. Coliforms as a measure of sewage contamination of the River Zambezi. Journal of Applied Bacteriology, **68**, 397-403.

[9] USEPA (United States Environmental Protection Agency): 2000, 'National Water Quality Inventory', Office of Water, United States Environmental Protection Agency, Available at: http://www.epa.gov/305b/2000report/. Accessed 26 April 2002.

[10] USEPA (United States Environmental Protection Agency): 2003, 'National pollutant discharge elimination system permit regulation and effluent limitation guidelines and standards for concentrated animal feeding operations (CAFOs); final rule', *Federal Register*. 68(29), 7176–7274

[11] Tian, Y. Q., Gong, P., Radke, J. D. and Scarborough, J.: 2002, 'Spatial and temporal modeling of microbial contaminants on grazing farmlands', *J. Environ. Qual.* **31**(3), 860–869.

[12] Lund, E., 1978. The survival of viral pathogens in water and waste in the tropics. Progress in Water Technology, **11**, 73-79.

[13] Melnick, J.L. and GERBA, C.P., 1980. The ecology of enteroviruses in natural waters. CRC Critical Reviews in Environmental Control, **10**, 65-93. O'Brien, R.T. and Newman, J.S., 1977. Inactivation of polioviruses and coxsackieviruses in surface water. Applied and Environmental Microbiology, **33**, 334-340.

[14] O'Donohue, P.J., 1995. Cryptosporidium and Cryptosporidiosis in man and animals. Internat. J. Parasitol., **25**, 139-155.

[15] O'Brien, R.T. and Newman, J.S., 1977. Inactivation of polioviruses and coxsackieviruses in surface water. Applied and Environmental Microbiology, **33**, 334-340

[16] Smith, H.V., Grimason, A.M., Benton, C. and Parker, J.F.W., 1991. The occurrence of *Cryptosporidium* spp. Oocysts in Scottish waters, and the development of a fluorogenic viability assay for individual *Cryptosporidium* spp. Oocysts. Water Science Technology, **24**, 169-172.

[17] Feresu, S.B., and Van Sickle, J., 1990. Coliforms as a measure of sewage contamination of the River Zambezi. Journal of Applied Bacteriology, **68**, 397-403.

[18] Moore, J. A., M. E. Grismer, S. R. Crane, and J. R. Miner. 1982. Evaluating dairy waste management systems' influence on coliform concentration in runoff. In Station Bulletin 658. Corvallis, Ore.: Oregon State University, Agricultural Experiment Station

[19] Larsen, R. E., J. R. Miner, J. C. Buckhouse, and J. A. Moore. 1994. Water−quality benefits of having cattle manure deposited away from streams. *Bioresource Tech.* 48(2): 113−118.

[20] Payment, P., A. Berte, M. Prevost, B. Menard, and B. Barbeau. 2000. ccurrence of pathogenic microorganisms in the Saint Lawrence River (Canada) and comparison of health risks for populations using it as their source of drinking water. *Canadian J. Microbiol.* 46: 65−576.

[21] Rosen, B. H. 2000. Waterborne pathogens in agricultural watersheds. Burlington, Vt.: USDA−NRCS Watershed Institute, University of Vermont

[22] Maier, R. M., I. L. Pepper, and C. P. Gerba. 2000. *Environmental Microbiology*. San Diego, Cal.: Academic Press

[23] Draft OSRAS Rev A*April 2001* additional information on pathogen transport and survival
M. l. Soupir1, S. Mostaghimi,D, E. R. Yagow1, C. Hagedorn D. H. Vaughan transport of fecal bacteria from poultry litter and cattle manures applied to pasture land Water, Air, and Soil Pollution (2006) 169: 125–136

[24] B. L. Benham, C. Baffaut, R. W. Zeckoski, K. R. Mankin, Y. A. Pachepsky, A. M. Sadeghi, K. M. Brannan, M. L. Soupir, M. J. Habersack 2006 modeling bacteria fate and transport in watersheds to support tmdls American Society of Agricultural and Biological Engineers ISSN 0001−2351