International Journal of Advance Research, IJOAR .org
Volume 1, Issue 3, March 2013, Online: ISSN 2320-9151

PREDICTIVE MODEL TO MONITOR THE RATE OF FECAL STREPTOCOCCI THROUGH FLUID PRESSURE IN LATERATIC AND SILT SAND FORMATION

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Abstract

Predictive model to monitor the rate of fecal streptococci through fluid pressure in lateritic and silt sand formation has been developed. The model was developed through a formulated governing equation that considered various variables in fluid pressure, these are influence that cause fast migration of microbes in soil and water environment. Formation characteristics were found to play major roles in the transport of streptococci in pheratic aquifers, the degree of permeability were not left behind, because it has a relationship between soil structural depositions. Environmental conditions were considered as factors that influences fast migration of the microbes in soil and water; high rain intensities increased the degree of fluid content in the soil. More so, high rate of permeability in soil structural deposition are found to increase the fluid pressure in homogenous formation, the deltaic nature were found to play major roles on the microbial migration process. These conditions were considered in developing the model equation that will monitor the rate of microbial transport in lateritic and silty sand formation. The developed model will definitely monitor the rate of concentration of these contaminants at different periods and depths in the study area.

KeyWords
Microbes in soil and water, urbanization, anthropogenic, groundwater, Laplace transformation

1. Introduction

Groundwater is the main resource of drinking water in many parts of the world. Contamination resulting from industry, urbanization and agriculture poses a threat to the groundwater quality (Amadi, 2007, 2009). The task of balancing groundwater protection and economic activities is challenging. Therefore, understanding the effects of different water management strategies and the role of climate change is essential for the sustainable use of coastal groundwater resources (Prasad and Narayana, 2004). According to Olobaniyi and Owoyemi (2006), the coastal regions of the world are the most densely populated areas in the world. More than one third of the world's populations are living within 100 km of the coastline (Hughes, et al., 1998). At the same time, the coastal regions provide about one third of the world's ecosystem services and natural capital (Aris, et al., 2007). Such growth is accompanied by increasing demand for water supply leading to the over-exploitation of the aquifer system and excessive drainage for land reclamation purposes. Contamination of the groundwater by natural means (seawater intrusion) and through anthropogenic means (human activities) cannot be ruled out in the area. The study is aimed at evaluating the quality of groundwater from the coastal plain-sand aquifer Port-Harcourt area with the view of determining its suitability for domestic, irrigational and industrial purposes. The heavy industrial and human activities in the area lead to the present study. The aquifer system in the area is largely unconfined, highly porous and permeable and the possibility of anthropogenic interference cannot be completely ignored, hence the need for this study.

Port-Harcourt, the 'garden-city and treasure base of the nation' is situated about 60 km from the open sea lies between longitude 6o55'E to 7o10'E of the

Greenwich meridian and latitude 4o38'N to 4o54'N (Fig. 1) of the Equator, covering a total distance of about 804 km2 (Akpokodje 2001). In terms of drainage, the area is situated on the top of Bonny River and is entirely lowland with an average elevation of about 15 m above sea level (Nwankwoala, 2005, 2007). The topography is under the influence of tides which results in flooding especially during rainy season (Nwankwoala and Mmom, 2007). Climatically, the city is situated within the sub-equatorial region with the tropical monsoon climate characterized by high temperatures, low pressure and high relative humidity all the year round. The mean annual temperature, rainfall and relative humidity are 30oC, 2,300 mm and 90% respectively (Ashton-Jones, 1998). The soil in the area is mainly silty-clay with interaction of sand and gravel while the vegetation is a combination of mangrove swamp forest and rainforest (Teme, 2002).

Flow from drywells under transient conditions can be described with the 2-dimensional saturated-unsaturated finite-difference model VS2DH 3.0 (Joel, 2004). This model, which is described in more detail Massmann (2003a), it can be used to simulate radial flow systems similar to what would be developed in the vicinity of drywells. Studies explain that the consequence for a dry well with double-barrel geometry at a site where the depth to groundwater is 48 feet below the bottom of the drywell and the saturated hydraulic conductivity is 0.02 feet per minute. (It should be noted that them convention used in this report is to define depth as the distance below the bottom of the drywell and not the depth below the land surface.) The unsaturated soil parameters were defined using the van Genuchten equation (Beyer, 1987, and, Lambe 1979 the vertical axis gives infiltration rate in cubic feet per second (cfs) and the horizontal axis is time in minutes (Joel, 2004).

Modeling microbial processes in porous media is essential to improving our understanding of the biodegradation of contaminants and the movement of pathogens. Microbial processes incorporate physicochemical processes and biological processes. Microorganisms and their transport in the environment is a complex issue of growing concern. Most reactive transport models only consider physicochemical processes. The impact of biological processes in a flowing groundwater system can only be evaluated within this physicochemical framework (Murphy and Ginn, 2000). The physicochemical processes are primarily based on the physical structure and chemical properties of the subsurface flow system and porous media. Microbial mobility dominated by physicochemical interaction with the porous media is mainly described with the colloid infiltration model.

The colloid filtration model has been found inadequately to simulate microbial transport in many cases. The discrepancies with the colloid filtration model can be presented in two ways. One is variation in collision efficiency among pathogen species, which can be significant for a single collector material. For example, in Bayyents et al 1998. Laboratory, 3 orders of magnitude variation in collision efficiency have been observed among bacterial species screened for affinity to borosilicate glass. Another is nonexponential decay in collision efficiency with distance of transport (Vaidyanathan and Tien 1988, Elimelech 1992, Albinger et al. 1994, Bayents et al., 1998, Camesano and Logan, 1998, Bai and Tien 1999, Harter et al., 2000, Li et al. 2004, Li and Johnson 2005). The standard colloid filtration model is based on a simple first-order expression for the decline in contaminant concentration C with distance z. That is, the standard clean bed filtration model predicts that concentration of fluid-phase and deposited particles decays exponentially with distance.

2. Theoretical Background

The rate microbial containment in Lateratic and silt formation is of serious concern to environmental health, microbial species streptococci is from the fecal coliform family that is predominant in the study area, the behavior of human activities is one the major cause of this microbes in soil and water environment, the management of our biological waste is the major cause of predominant deposition of microbes in the study area. Rivers state is in deltaic environment of Niger Delta region in Nigeria, the population status is over five million one hundred and eighty-five pupils from the national population commission, the rate of population in the state generate lots of waste, more so poor management of waste generated develop more of these type of microbial containment in the soil and water, the soil structural stratification are the causes of fast migration of these source of containment to soil and water environment. Formation characteristics in the study location where found to have influence on fast transport of this type of microbial specie in soil and water environment. In other to solve this threat of life from this type of microbial species, mathematical equation were developed, this equation were formulated considering the variables that play a major roles in fast migration of the microbes in soil and water environment, this variables are the formation characteristics that influence the transport of streptococci in soil and water, base on this condition the variables that influence the transport of the microbes were sorted out to form a system, these variables where denoted with mathematical symbols.

This formulated a governing equation to monitor the rate of fecal streptococci, through fluid pressure in lateritic and silty sand formation. The governing equations are expressed below.

3. Governing equation

$$Sop\frac{\partial^2 p}{\partial t^2} + \left[\varepsilon w\frac{\partial p}{\partial t}\right] w\frac{\partial p}{\partial t} - \frac{\partial p}{\partial x_1}\left[\frac{K_1 p}{\mu}\right]\left[\frac{\partial p}{\partial x_j} + pg\frac{\partial p}{\partial x_i}\right] = QP_z \qquad \text{.............} \quad (1)$$

Taking Laplace transformation of (1)

$$\frac{\partial^2 p}{\partial t^2} = S^2P_{(t)} - SP - P_{(0)} \qquad \text{...} \quad (2)$$

$$\frac{\partial p}{\partial t} = SP_{(t)} - P_{(t)} \qquad \text{...} \quad (3)$$

$$\frac{\partial p}{\partial t} = SP_{(t)} - P_{(t)} \qquad \text{...} \quad (4)$$

$$\frac{\partial p}{\partial x} = SP_{(x)} - P_{(x)} \qquad \text{...} \quad (5)$$

$$\frac{\partial p}{\partial x} = SP_{(x)} - P_{(x)} \qquad \text{...} \quad (6)$$

$$P = P_{(0)} \qquad \text{...} \quad (7)$$

Submitting equation (2), (3), (4), (5), (6) and (7) into equation (1), yields

$$Sop\left[S^2P_{(t)} - SP_{(t)} - P_{(0)}\right] + \varepsilon w\left[SP_{(t)} - P_{(0)}\right]w\left[SP_{(t)} - P_{(0)}\right] - \left[SP_{(x)} - P_{(0)}\right]\frac{Kp}{\mu}$$

$$\left\|SP_{(t)} - P_{(0)} + Pg\,(SP_{(t)} - P_{(0)})\right\| = QPz \qquad \text{.....................} \quad (8)$$

Applying Laplace transformation for the above developed equation, the expression from equation one to seven were to transform the equation into Laplace, this expression yield equation 8 where the equation are Laplace transformation, the expressed solution were applied considering the stated parameters that influence the system, these expressed the role on each variable that played majored role in microbial migration to ground aquifers.

$$-2SP_{(x)}P_{(0)}-(P_{(0)})^2+Pg\left(SP_{(t)}\right)^2-2SP_{(x)}P_{(0)}-(P_{(0)}{}^2)=QP_z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

Equating (9) with respect to time, *t*, we have

$$Sop\left[S^2P_{(0)}-SP_{(t)}-P_{(0)}\right]+\varepsilon w^w\left[(SP_{(t)})^2-2SP_{(0)}+P_{(0)})^2\right]=0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

Equating (9), with respect to Time direction of flow gives

$$-\frac{Kp}{\mu}\left(Sp_{(x)}\right)^2-2SP_{(t)}P_{(0)}+\left(P_{(0)}\right)^2+Pg\left(Sp_{(x)}\right)^2-2SP_{(t)}P_{(0)}+\left(P_{(0)}\right)^2=QP_Z \quad \ldots\ldots\ldots\ldots\ldots \quad (11)$$

Rearranging (11), yields

$$a^2-2ap+P(a-p)^2$$

$$\left(1+Pg\right)\left(Sp_{(x)}\right)^2-\left(1+Pg\right)2SP_{(t)}P_{(0)}+\left(1+Pg\right)\left(P_{(0)}\right)^2=\frac{QP_Z\mu}{K,P} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

Equation 9 streamline with respect to time were by the equation expressed consider the migration under the influence of time on the direction of flow. It is where equation 10 and 11 where rearranged to yield equation 12, it expressed the role of time influence on the fluid pressure, this condition integrated the migration process whereby the derived equation express the subject relation on the variation of the concentration influence through the fluid pressure in the system.

$$\left[\left(Sp_{(x)}\right)^2-2SP_{(t)}P_{(0)}+\left(P_{(0)}\right)^2\right]\left(1+Pg\right)=-\frac{QP_Z\mu}{K,P} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

$$\left(Sp_{(x)}\right)^2 - 2Sp_{(x)}P_{(0)} + \left(P_{(0)}\right)^2 = -\frac{QP_Z\mu}{K,P(1+Pg)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

$$\left[Sp_{(x)} - P_{(0)}\right]^2 = -\frac{QP_Z\mu}{K,P(1+Pg)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

$$\left[Sp_{(x)} - P_{(0)}\right]^2 Sp_{(x)} - P_{(0)} = -\sqrt{\frac{-QP_Z\mu}{K,P(1+Pg)}} = \pm i\sqrt{\frac{QP_Z\mu}{K,P(1+Pg)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

$$P_{(x)} = P_{(0)} \pm i\sqrt{\frac{QP_Z\mu}{K,P(1+Pg)}} \quad \ldots\ldots\ldots\ldots\ldots \quad (17)$$

$$Sp_{(x)} = P_{(0)} \pm i\sqrt{\frac{QP_Z\mu}{K,P(1+Pg)}} \quad \ldots\ldots\ldots\ldots \quad (18)$$

When $x > 0,\ P_{(0)} = P_0$

$$P_{(x)} = \frac{P_0}{S} \pm i\sqrt{\frac{QP_Z\mu}{K,P(1+Pg)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

Hence in any direction *x*, we have

$$P_{(x)} = \ell^{P_0/S}\left[A\,Cos\sqrt{\frac{\frac{QP_Z\,\mu}{K,P(1+Pg)}}{S}} + B\,Sin\sqrt{\frac{\frac{QP_Z\,\mu}{K,P(1+Pg)}}{S}}\right]x \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

$$\Rightarrow \quad P_{(x)} = \ell^{P_{0t}}\left[A\,Cos\sqrt{\frac{\frac{QP_Z\,\mu}{K,P(1+Pg)}t}{S}} + B\,Sin\sqrt{\frac{\frac{QP_Z\,\mu}{K,P(1+Pg)}t}{S}}\right]x \quad \ldots\ldots\ldots\ldots \quad (21)$$

Again, we consider (10) so that we have

$$Sop\left[S^2P_{(t)} - SP_{(t)} - P_{(0)}\right] + \varepsilon w^w\left[(SP_{(t)})^2 - 2SP_{(t)}P_{(0)} + P_{(0)})^2\right] = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

$$Sop\left[S^2P_{(t)} - SP_{(t)} - P_{(0)}\right] = -\varepsilon w^w\,(SP_{(t)} - P_{(0)})^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

$$\frac{S^2P_{(t)} - SP_{(t)} - P_{(0)}}{\left(SP_{(t)} - P_{(0)}\right)^2} = \frac{-\varepsilon w^w}{Sop} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

$$SP_{(t)} - P_{(0)} \neq 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (25)$$

Considering the left hand side of the number of (23) gives

$$P_{(t)} = \frac{S \pm \sqrt{S^2 + 4S^2 P_{(o)}}}{2S^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (26)$$

$$P_{(t)} = \frac{\frac{1}{2S} \pm \sqrt{1 + 4P_{(o)}}}{2S} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (27)$$

When $t > 0,\ P_{(o)} = P_o$

So that $P_{(t)} = \frac{1}{2S} \pm \frac{\sqrt{1 + P_o}}{2S}$

Hence $P_{(t)} = A\ell^{\frac{1}{2}\left(1 + \sqrt{1 + P_o}\right)^t} + B\ell^{\frac{1}{2}\left(1 - \sqrt{1 + P_o}\right)^t}$ $\quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (28)$

Since the Denominator of the left hand side of (23) has equal roots;

$$P_{(t)} = \frac{-\varepsilon w^w}{Sop}\left(C + Dt\right)\ell^{(t - P_o)^t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

Combining equation (28), we have

$$P_{(t)} = \frac{-\varepsilon w^w}{Sop}\left(C + Dt\right)\ell^{(t - P_o)^t} + A\ell^{\frac{1}{2}\left(1 + \sqrt{1 + P_o}\right)^t} + B\ell^{\frac{1}{2}\left(1 - \sqrt{1 + P_o}\right)^t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

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

$$\boxed{P_{(x,v)} = A\ell^{\frac{1}{2}\left(1 + \sqrt{1 + P_o}\right)^t} + B\ell^{\frac{1}{2}\left(1 - \sqrt{1 + P_o}\right)^{\frac{x}{v}}} - \frac{\varepsilon w^w}{Sop}\left(C + Dt\right)\ell^{(1 - P_o)^{\frac{x}{v}}}} \quad \ldots\ldots\ldots\ldots \quad (31)$$

The expressions from equation 15 to 30 relate the variables at several phases, this include the microbial species that change there microbial transport base on the stated parameters, including there behavior in lateritic and silt formation. In other to thoroughly monitor the rate of concentration and there death rate, the level of microbial population, in equation 31 where expressed relating to the model equation in term of distance and velocity, the fluid pressure are influenced by the velocity of transport and these conditions are from the rate of porosity at silty formation, this region of the soil formation is highly contaminated, both parameters have a relation on soil structural deposition, this will definitely increase the fluid pressure and the microbial transport, finally, the governing equation derived expressed all the influencial parameters that will definitely monitor the rate of streptococci in lateritic and silt formation. These condition are mostly in deltaic environment, because it is predominant with homogenous formation and shallow aquifer deposition, this is a serious threat to water quality from this type of microbial specie in the study area.

4. Conclusion

The governing equation to monitor the rate of fecal streptococci through fluid pressure in lateritic and silt formation has bee developed, the equation were developed considering the major variables that cause fast migration of this type of microbial containment, the major variables are from the formation characteristic, geological histories where thoroughly examine to ensure that other influence were not left behind on developing the equation, fluid pressure play major roles on microbial transport depending on the rate of soil stratification, this formation varies and this influence the rate of microbial concentration at every period and depth. The study areas are deltaic in environment and homogenous formation are predominant with alluvium deposit in the study area. The model developed considered these variables as stated in the model equation through mathematical tools, finally the model should be a base line to monitor the rate of fecal streptococci influenced by fluid pressure in deltaic environment.

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