International Journal of Sustainable Energy and Environment
Vol. 1, No. 8, September 2013, PP: 127 -135, ISSN: 2327- 0330 (Online)
Available online at www.ijsee.com

Research article

MODELING BACILLUS MIGRATION INFLUENCED BY MASS WATER CONTENT IN GRAVEL FORMATION IN COASTAL AREA OF ABONNEMA, RIVERS STATE OF NIGERIA.

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Abstract

Modeling bacillus migration influenced by mass water content in gravel formation in coastal area of Abonnema has been evaluated. The concept was to monitor the migration process of bacillus under the influence of mass water content through degree of saturation and hydraulic conductivity of the strata. The study area is predominant with alluvium depositions that reflect homogeneous gravel formation in coastal shallow aquifers. Subject to this relation, mass water content precisely was expressed in the system to determine its influence on bacillus migration process in gravel formation. These formulated a system that established the governing equation, which expressed mass water content and formation characteristics through the geologic history of coastal environment. The study is imperative because the established mathematical model will definitely monitor the influence of mass water content on bacillus migration process in coastal fresh water aquifers at shallow depositions. Practicing engineers and scientists will in this dimension be able to predict the behaviour of bacillus migration under the influence of mass water content.

Keywords: Modeling bacillus, mass water content and gravel formation.

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1. Introduction

The Clean Water Act (CWA) requires states to assess state water bodies, usually via monitoring data, to determine if pollutants are present in sufficient quantities to prevent the waters from being utilized for their designated purposes (USEPA, 2002). When a water body, or section of a water body, is unable to be used for its designated purposes, it is considered to be impaired. Once a water body is classified as impaired and added to the 303(d) list, the CWA requires states to develop a Total Maximum Daily Load (TMDL) for the water body (USEPA, 2000). Development of TMDLs relies heavily on Computer models to identify pollutant contributors and to predict how different pollutant allocations in a watershed might affect the impaired water body. In Virginia, approximately 73% of impaired waters are impaired due to fecal coliforms (FC) (VDEQ, 2002). Current models used to develop bacterial TMDLs use laboratory-derived bacterial parameters that might be inappropriate for simulating field conditions. Once appropriate bacterial relationships are determined Pathogens are organisms, such as viruses and some bacteria, which are able to inflict damage on hosts that they infect (Madigan et al., 2000). Enumeration of pathogens is often time-consuming, technically intensive, and costly; therefore, pathogen presence is often estimated through the utilization of indicator organisms. Because FC and EC are found in the intestines of warm-blooded animals, their presence is indicative of fecal contamination. Potential sources of fecal contamination in water bodies include land-applied manure and sludge, manure from grazing animals, wildlife feces, combined sewer overflows, and failing septic systems. Youngblood-Myers (2001) investigated a potential alternative to testing waters for indicator organisms. Processes that are important to bacterial survival should be included in a bacterial nonpoint source model, including bacterial growth/die-off; sorption of bacteria to the soil matrix; partitioning of bacteria between water and sediment; and effects of management practices (Crane and Moore, 1985; Coyne and Blevins, 1995; Huysmans and Verstraete, 1993; Walker et al., 1990, Reddy et al., 1981). Mancini (1978) and Crane and Moore (1985) described three commonly observed patterns of coliform die-off: first-order decay; bacterial growth followed by first-order die-off; and die-off rate that changes with time. The first-order decay equation often used to describe bacterial die-off is expressed as Chick's Law (Crane and Moore, 1985) Modifications of Chick's Law by Mancini (1978), Polprasert et al. (1983), and Reddy et al. (1981) adjust the die-off rate constant for environmental impacts of temperature, solar radiation pH, and/or soil moisture content. Polprasert et al. (1983) researched the ability of waste stabilization ponds to reduce total and fecal coliform concentrations in wastewater, which was approximately the equivalent bacterial concentration of domestic waste, under both controlled (laboratory) and field conditions. Stephenson and Rychert (1982), Gary and Adams (1985), and Sherer et al. (1988) showed that disturbing bottom sediments resuspends fecal bacteria in overlying waters. Stephenson and Rychert's (1982) objective was to determine if a relationship existed between elevated EC concentrations in rangeland streams with bottom sediments. Coyne and Blevins (1995) used a pipette method for particle size analysis of aliquots of runoff samples from plots with vegetated filter strips (VFSs) that had turkey litter applied to them to determine if bacteria were associated preferentially with a specific particle size. Reddy et al. (1981) calculated retention coefficients (i.e., adsorption coefficients) for total coliforms and FC in river sediments, but these coefficients are not necessarily applicable for field soils. Huysmans and Verstraete (1993) found that *Escherichia coli* (EC) strains preferentially adhered to finer soils, as well; they specifically investigated EC adhesion to kaolinite, montmorillinite, and a clay loam soil.

2. Theoretical background

Mass water content are based on the volume of water that deposits in the porous medium on different soils but more volumetric on porous medium. These are influenced by hydraulic conductivities of a formation that transmits groundwater aquifers. Subject to this relation, degree of saturation is one of the parameters that express mass water content under the influence of high rain intensities based on climatic conditions. Bacillus is a contaminant found to deposit in coastal deltaic environment that lap up with marine deposit with short fresh water aquifers at shallow depth depositing in homogeneous alluvium strata over 800ft. such homogenous strata develop high mass water content reflecting environmental influence through the climatic condition under the pressure of high rain intensities. The depositions of the formations develop variations of mass water content under the microspores of formation variables through t intercedes of the strata. In line with contaminant migration, it is obvious that such deposition will reflect on the migration of bacillus in coastal fresh water aquifers. Expressing such microbial transport in shallow aquiferous zones is based on hydrogeologic studies carried out to monitor the behaviour of groundwater quality and depositions at different strata. Such pressure from the microbes are influenced through this dimension as it pressure their behaviour, conditioning their migration and its process under the influence of formation characteristics such as microspores of the strata and degree of saturation which express the mass content in the formation. Mathematical models are developed to establish a relationship between mass water content and bacillus depositions and its migration process in order to express their influence on coastal formations. Subject to this relation, coastal formations establish several variations based on climatic conditions that reflect the geologic history of the soil.

$$\theta_w V \frac{\partial c}{\partial t} = \theta_M \frac{\rho_B}{\rho_W} V \frac{\partial^2 c}{\partial x^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

3. Governing equation

Equation (1) is the expressed governing equation that describes mass water content on the deposition of bacillus. The derived solutions were formulated based on the variables that were formulated as a system denoted by mathematical symbols that expressed the governing equation. The governing equation is to establish the relationship between mass water content and the deposition of bacillus contaminant under the influence of velocity of solute. The velocities of solute express its function through the rate of permeability under hydraulic conductivity of the soil. This formulates the system mathematically to be derived to get a model that will monitor mass water content and bacillus deposition in the study location.

Substituting solution C = ZT into (1), we have

$$\theta_w vZT^1 = \vartheta \frac{\rho_b}{\rho_w} VZ^{11}T \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (2)$$

$$\vartheta_w \frac{T^1}{T} = -\theta_M \frac{\rho_b}{\rho_w} V \frac{Z^{11}}{Z} T \qquad \ldots\ldots\ldots\ldots\ldots\ldots \tag{3}$$

$$\theta_W \frac{T^1}{T} \quad -\vartheta \frac{\rho_b}{\rho_w} V \left(\frac{Z^{11}}{Z} \right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots \tag{4}$$

$$\vartheta_W V \frac{T^1}{T} \quad -\frac{Z^{11}}{Z} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \tag{5}$$

Considering when Ln x $0 \rightarrow$

$$\theta_W V T^1 = \vartheta_M \frac{\rho_b}{\rho_W} V \frac{Z^{11}}{Z} - T = \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \tag{6}$$

$$\theta_W V \frac{T^1}{T} = \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \tag{7}$$

$$\frac{Z^{11}}{Z} = \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \tag{8}$$

$$\theta_M \frac{\rho_b}{\rho_W} V = \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \tag{9}$$

This implies that equation (10) can be expressed as:

$$\theta_M \frac{\rho_b}{\rho_w} v \frac{Z^{11}}{Z} = \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \tag{10}$$

$$\theta_M \frac{\rho_b}{\rho_w} V \frac{Z^2}{Z} = \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \tag{11}$$

$$\vartheta_W V \frac{dy^2}{dx^2} = \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \tag{12}$$

$$\theta \frac{\rho_b}{\rho_w} V \frac{dy^2}{dz^2} = \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \tag{13}$$

$$\vartheta_W V \frac{d^2 y}{dz^2} = \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \tag{14}$$

$$\frac{d^2 y}{dz^2} = \frac{\lambda^2}{\vartheta_W V} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (15)$$

$$d^2 y = \left(\frac{\lambda^2}{\theta_W V}\right) dz^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (16)$$

$$\int d^2 y = \int \frac{\lambda^2}{\vartheta_W V}\, dz^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (17)$$

$$dy = \frac{\lambda^2}{\vartheta_W V} x\ dz \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (18)$$

$$\int dy = \int \frac{\lambda^2}{\vartheta_W V} Z\ dz + C_1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (19)$$

$$y = \frac{\lambda^2}{\theta_w V} Z + C_1 x + C_2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (20)$$

$$y = \frac{\lambda^2}{\theta_W V} + C_1 x + C_2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (21)$$

$$y = 0$$

$$\Rightarrow \frac{\lambda^2}{\theta_W V} X^2 + C_1 x + C_2 = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (22)$$

The expressed derived solutions are descretized mathematically to ensure that their relationships are expressed including their functionalities in details as it is formulated in the system. Subject to this condition by deriving this governing equation, it has detailed various parameters functions and their influence on deposition of the contaminants in coastal environment. Mass water content from this dimension has been thoroughly detailed from its origin including its further influence from structural stratification under the influence of coastal environment. The expressed derivations are structured with this mathematical application to ensure that various variables are thoroughly detailed with its function as it is expressed from equations (2) to (22).

Applying quadratic expression, we have

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (23)$$

Where a = $\frac{\lambda^2}{\theta_W V}$, b = C_1 and c = C_2

$$X = \frac{-(C_1) \pm \sqrt{(C)^2 - 4\left(\frac{\lambda^2}{\theta_W V}\right)C_2}}{2\frac{\lambda^2}{\theta_W V}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (24)$$

$$= \frac{-C_1 \pm \sqrt{C_1^{\ 2} - 4C_2\frac{\lambda^2}{\theta_W V}}}{2\frac{\lambda^2}{\theta_W V}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (25)$$

$$X = \frac{-C_1 + \sqrt{C_1^{\ 2} - 4C_2\frac{\lambda^2}{\theta_W V}}}{2\frac{\lambda^2}{\theta_W V}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (26)$$

$$X = \frac{-C_1 + \sqrt{C_1^{\ 2} - 4C_2\frac{\lambda^2}{\theta_W V}}}{2\frac{\lambda^2}{\vartheta_W V}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (27)$$

$$X = \frac{-C - \sqrt{C_1^{\ 2} - 4C_2\frac{\lambda^2}{\vartheta_W V}}}{2\frac{\lambda^2}{\vartheta_W V}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (28)$$

The application of quadratic function are introduced to establish the function of the variables in the system, the express parameters were integrated in quadratic function to structure the parameters in other develop common ground that will express the relative influence of the system on the deposition of bacillus in coastal area, the influence of formation characteristics such as degree of saturation reflect the rate of hydraulic conductivity in the formation in the strata, the expression from this dimension streamline the behaviour of the microbes in soil and water environment.

Substituting equation (20) to the following boundary conditions and initial values condition

$$t = 0 \quad C = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (29)$$

Boundary values are considered in the condition, this establish the limits in the system base on the transport process under the influences of the deposited strata in the study location, the establishment of these limit provide the platform of the transport process and the structural deposition of the formations to determined the considered limits as it determine in equation [29].

Therefore, $X_{(x)} = C_1\ell^{-mx} + C_2\ell^{m_2x}$ …………………………… (30)

$$C_1 \, Cos \, M_1 x + C_2 \, Sin \, M_2 x \qquad \text{……………………………} \qquad (31)$$

$$y = \frac{\lambda^2}{\theta_W V} + C_1 + C_2 \qquad \text{……………………………} \qquad (32)$$

$$C(x,t) = \left(C_1 \, Cos \, M_1 \frac{\lambda^2}{\vartheta_W V} Z + C_2 \, Sin \, M_2 \frac{\lambda^2}{\theta_W V} Z \right) \qquad \text{……………………} \qquad (33)$$

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

Therefore, equation (33) can be expressed as:

$$C(x,t) = \left(C_1 \, Cos \, M_1 \frac{\lambda^2}{\theta_W V} \frac{v}{t} + C_2 \, Sin \, M_2 \frac{\lambda^2}{\theta_W V} \frac{v}{t} \right) \qquad \text{……………………} \qquad (34)$$

The expression in [34] is the final derived model to examine the rate of mass water content and the deposition of bacillus in coastal area of Abonnema. The system were formulated reflecting every variable that are influential to the migration of bacillus in coastal location, mass water content are found to influence the deposition of bacillus are pressured by high degree of saturation, this is through the influence of environmental condition that express geologic history in the study area. More so, the deltaic natures are reflected on the formation characteristics as mass water content is considered in this system. The state parameters influence bacillus deposition. Development of this mathematical equation were derived to generate this final model equation, this is to streamline the functionality and relationship of various variables that influence the migration process of bacillus, these conditions are through the deposition of mass water content in porous medium. Fresh water aquifers found are coastal locations are reflected in these conditions to be the paramount influence through the alluvium deposition in the deltaic formation.

4. Conclusion

Bacillus deposition in mass water content shows the reflection of high degree of hydraulic conductivity in the porous medium, although, variations are established since the coastal environment deposits slight lateritic soil that should deposit a lower mass water content and hydraulic conductivity in the environment. But the focus of this study is precisely on the alluvium depositions that reflect homogenous system under the influence of deltaic environment. To structure this condition, mathematical model were found suitable to mathematically develop a model that will structure the system reflecting the established relationship of mass water content and bacillus deposition in the coastal location. Such formations developed were to streamline the influence that expressed fast migration of bacillus in alluvium deposited environment. Subject to this relation, formation variables influence was confirmed to structure the behaviour of bacillus migration process subjecting them to be influenced by stratification of the formation in the coastal environment. The model will definitely monitor the behaviour of bacillus under the influence of mass water content in the study location.

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