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Research article

CONSERVATION MASS TRANSPORT OF PATHOGENIC DEPOSITION OF NONREACTIVE ISOTROPIC HOMOGENEOUS STEADY STATE FLOW IN UNCONFINED BED IN FINE AND GRAVEL SAND FORMATION AT EMUOHA RIVERS STATE OF NIGERIA

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Abstract

The conservation of mass transport of pathogen deposition are determine by several factors in the system, numerous approach has been applied to monitor the transport of pathogen in this condition, but couldn't develop effective solution, the application of this approach are base on thorough investigation previously carried in the study area, the system were formulated base on the results carried through monitoring and evaluation in the study area. Mathematical approach were find suitable to mathematically develop model that will monitor the transport of the pathogen, the study defined the objective to ensure that they are thoroughly achieved, the developed governing equation were expressed base on the parameters that influences the transport system. Expert in the field will applied this model to improve on the prevention of pollution sources from pathogen in the study area.

Keywords: conservation mass, transport of pathogen, steady state and unconfined bed

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 Eluozo and Afiibor 2013). 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 Eluozo and Afiibor 2013). 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 Eluozo and Afiibor 2013). 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 Eluozo and Afiibor 2013). 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 the 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 no exponential 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 condition of flow in soil and water environment depends on the structural strata influenced by the geological setting in the study location, the condition of the strata develop structural setting of conservative condition on mass transport of pathogenic deposition in soil and water environment .several minerals are also found to deposit in the formation, there integration of the phase deposit together in the same stratum or strata, the mineral were found not reacting with the deposited minerals, this condition may develop influences of pathogenic deposited originated from geological setting in the study area. Mass transport of pathogenic origin in fine and gravel formation in isotropic homogeneous steady state flow in unconfined bed has developed lots variation in the formation. This implies that the structural deposition of the formation deposit uniform parties size distribution of the grain size, it is influenced by flow direction and its velocity in the study location. The environment is conservative resulting mass transport of pathogenic deposition in the study location. The deposition of nonreactive substance in the deposited fine and gravel formation may be base on the formation influences resulting rapid increase pathogenic origin under conservative state. Due nonreactive condition with any deposited mineral may result in fast transport from high degree of porosity, it may also develop high concentration of pathogen in unconfined bed, more so the deposition of fine and gravel strata in homogenous setting at various bed implies that the structural deposited influenced will definitely result in fast migration with high concentration to unconfined bed, the reflection from formation characteristics are also from degree of void ratio in the formation , definitely the structure of these setting implies that the mass transport of the microbes are influences with the stated condition expressed in the system. Homogeneous steady state flow in this direction are influences by formation deposited variations reflected from porosity of the soil and the conservation of the formation that ease the transport of pathogen to unconfined bed. The variable expressed from the system generated the governing equation, the developed governing equations establish some other influence mineral in the study area, and the governing equations are expressed bellow.

3. Governing equation

$$Vn\frac{\partial C}{\partial t}(x,t) = nV_x\frac{\partial C}{\partial x}(x,t) + nD\frac{\partial^2 C}{\partial x^2}(x,t) \qquad \text{.................... (1}$$

The expression in [1] is the governing equation to monitor conservation mass transport of pathogenic deposition of nonreactive isotropic homogeneous steady state flow in unconfined bed. the principal equation defined the system observation in conservative non reactive condition of pathogenic deposition in the study area, the parameters in the principal equation defined the system objective to archive in the study, the expressed governing equation will be derived by applying other mathematical method that will ensure that the model develop proof the system objective , this are base on the transport influence reflected in the formation and other deposited minerals influential to the transport of pathogenic deposition in silty and gravel formations.

$$\frac{\partial C}{\partial t} = S^1C(t) - C(o) \qquad \text{.................... (2)}$$

$$\frac{\partial C}{\partial x} = S^1C(x) - C(o) \qquad \text{.................... (3)}$$

$$\frac{\partial^2 C}{\partial x^2} = S^{11}C(x) - S^1C(o) - C(o) \qquad \text{.................... (4)}$$

Substituting (2), (3), (4) into equation (1) gives

$$S^1C(t)\ (t) - Vn\left[S^1C(x) - C(o)\right] = Vn\left[SC(x) - C(o)\right] + nD$$
$$\left[S^2C(x) - SC(o) - C(o)\right] \qquad \text{.................... (5)}$$

$$S^1(t) - VnS^1C(o) = nVxS^1C(x) + nDS^{11}C(x) - S^1C(x) \qquad \text{.................... (6)}$$

$$C(x)\frac{1}{S}\left[VnS^1C(t) - nVxS^1C(x) + nDS^{11}C(x) - S^1C(x)\right] \qquad \text{.................... (7)}$$

$$C(x)\,\frac{1}{S^{1}}\,\left[VnS^{1}C(t)-nVx\,S^{1}C(x)+nDS^{11}C(x)-S^{1}C(x)\right]\ldots\ldots\ldots\ldots\ldots \quad (8)$$

$$C(x)=\frac{VnS^{1}C(t)-nVx\,C(x)+nDS^{1}}{S} \quad \ldots\ldots\ldots\ldots\ldots (9)$$

$$C(x)=VnC(t)-nVx\,C^{1}(x)+nDC^{11} \quad \ldots\ldots\ldots\ldots\ldots (10)$$

$$C(x)=\frac{VnS^{1}C(t)=nVx+nDS^{1}}{S} \quad \ldots\ldots\ldots\ldots\ldots (11)$$

$$C(x)=\left[Vn-nVx+nDS^{11}\right]C(t) \quad \ldots\ldots\ldots\ldots\ldots (12)$$

$$S^{1}C(x)=\left[Vn-nVx+nDS^{11}\right]C(t) \quad \ldots\ldots\ldots\ldots\ldots (13)$$

$$C(x)=\frac{S^{1}C(x)}{Vn+nVxS^{1}+nDS^{11}} \quad \ldots\ldots\ldots\ldots\ldots (14)$$

$$C(t)=\frac{S^{1}(x)}{Vn+nVx+nD} \quad \ldots\ldots\ldots\ldots\ldots (15)$$

Furthermore, considering the boundary condition, we have

$$\text{At } t=0 \quad C^{1}(o)=C(o)=0 \quad \ldots\ldots\ldots\ldots\ldots (16)$$

In other to ensure that objective of the transport and other deposited influence express their function in the transport system, boundary values were introduced in the derived solution, this to determine every limited movement in the formation, so that the deposition and migration of mass transport of pathogenic deposition can be observed, the migration of the microbes in soil and water environments are influenced by formation deposited characteristics , therefore the system defined the rate of influenced at every stage of migration by introducing boundary values at different strata. some of the boundary condition has been stated above, they were integrated in the derived solution including the introduced state boundary values in [16] that will be integrated bellow.

$$VnS^{1}C(t)-nVxS^{1}C(x)+nDS^{11}\;S^{1}C(x)C(o)=0 \quad \ldots\ldots\ldots\ldots\ldots (17)$$

$$C(t)=\frac{0}{Vn-nVxS^{1}+nDS^{11}} \quad \ldots\ldots\ldots\ldots\ldots (18)$$

Considering the following boundary condition when

At $t > 0 \quad C^1(o) = Co$ ………………… (19)

Applying the boundary condition into this equation

$$VnS^1C(t) - VnC(o) - Vn - nVxS^1 C(x) - nVxCo - S(x) + nDS^{11}$$

$$C(x) + nDCo + S^1C(x) \quad \text{………………… (20)}$$

$$VnC(t) - VnxC(x) = nVxSC(o)\, VnCo - nVxCo + nDC(o) \quad \text{……………… (21)}$$

$$C(t) = [VnS - Vn - nVx + nD]Co \quad \text{………………… (22)}$$

$$C(t) = VnS - Vn - nVx + nD\ Co \quad \text{………………… (23)}$$

$$C(t) = \left(\frac{VnS - Vn - nVx + nD}{VnS - Vn - nVx + nD}\right) Co \quad \text{………………… (24)}$$

Applying quadratic expression to determine denomination for the equation

$$Vn - nVx + nD = 0 \quad \text{………………… (25)}$$

Applying quadratic expression, we have

$$s = \frac{-b \pm \sqrt{b^2 - 4ac}}{2ac} \quad \text{………………… (26)}$$

Where $a = Vn$, $b = nVx$ and $c = nDCo$

Application of other mathematical methods were necessary for the study, the derived solution at the stage has confirm the integration and expression of every function of the parameters in the system , the transport as it is expressed above in the governing equation defined the behaviour of every parameter and will ensure every parameters expressed their function as stated here.

$$X = \frac{-C_1 + \sqrt{C_1{}^2 - 4C_2 \dfrac{\lambda^2}{\theta wV}}}{2\theta wV} \quad \text{………………………….. (27)}$$

$$X = \frac{-C_1 - \sqrt{C_1{}^2 - 4C_2 \dfrac{\lambda^2}{\theta wV}}}{2\dfrac{\lambda^2}{\theta wV}} \quad \text{………………………….. (28)}$$

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

$$t = 0, C = 0 \quad \text{.............................} \quad (29)$$

Therefore, $X_{(x)} = C_1 e^x - e^{-mx} + C_2 M^{em2x}$ .... (30)

$$C_1 Cos M_{1x} + C_2 Sin M_{2x} \quad \text{.............................} \quad (31)$$

$$y = \frac{\lambda^2}{\theta w V} + C_1 + C_2 \quad \text{.............................} \quad (32)$$

$$C(x,t) = \left[C_1 Cos M_1 \frac{\lambda^2}{\theta w V} x + C_2 Sin M_2 \frac{\lambda^2}{\theta w V} x \right] \text{..............} \quad (33)$$

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

Therefore, equation (33) can be expressed as:

$$C(x,t) = \left[C_1 Cos M_1 \frac{\lambda^2}{\theta w V} \frac{v}{t} + C_2 Sin M_2 \frac{\lambda^2}{\theta w V} \frac{v}{t} \right] \text{..............} \quad (34)$$

The expression from the governing equation is the derived model that will to monitor conservation mass transport of pathogenic deposition of nonreactive isotropic homogeneous steady state flow in unconfined bed in fine and gravel sand formation at emuoha, the developed model establish the objective of the study defined in the system, the derived model considered several condition that influences the transport in the study area. The parameters were defined to express their various function at the stage the derived solution introduce an mathematical method that produced the objective of the parameter in to achieved in the transport system.

4. Conclusion

The study has establish the system that defined the rate of mass transport of pathogenic deposition of nonreactive isotropic homogeneous steady state flow in unconfined bed, it is predominantly deposited in fine and gravel sand formation at emuoha, numerous condition to monitor the transport system were considered, the conservative condition including non reactive isotopic homogeneous steady state in unconfined bed, these are base on the deposition of the formation, the parameters stated in the system defined the influences, the formation in homogeneous in nonreactive condition implies that the deposited formation express the stated condition and this influences, it has thoroughly develop refection on the deposition and migration of pathogenic in the formation. The formation characteristics that determine the migration is the permeability percentage of the soil, although it was render insignificant in the developed system, but for detail objective it is for certainty that the rate of flow on mass transport of pathogen cannot take place without permeability of the formation determinant, the rate of flow are determined by this parameters, therefore mass transport of pathogen in conservative nonreactive condition are monitored, it is determined through the rate of permeability coefficient with respect to time of transport. The study is imperative because it has express the behaviour of the microbes in homogeneous and conservative condition in the study area.

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