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Research article

MODELING OF KLEBSIELLA PNEUMONAE TRANSPORT INFLUENCED BY POROSITY AND DISPERSION IN HOMOGENEOUS SILTY FINE SAND FORMATION IN EMUOHA, RIVERS STATE OF NIGERIA

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Abstract

Modeling of Klebsiella Pneumonae transport influenced by porosity and dispersion in homogeneous silty fine sand formation has been carried out. The model was expressed to monitor the rate of dispersion and porosity of the soil formation under exponential phase. This concept was found necessary from risk assessment carried out, which proved the dispersion rate of klebsiella pneumonae in soil and water environment. Accumulation of these microbes may be found in lateritic soil in some conditions under the influence of low porosity, but climatic conditions including deltaic nature of the soil definitely increased the rate of fast migration of the microbes in the porous medium. Regeneration of these contaminants is another factor that increased high concentration of the microbes in the porous medium, causing degradation of groundwater quality that reflects the deposition of such shallow aquifers. The study is imperative because mathematical model developed will streamline various functions of porosity and dispersion and in a nutshell, develop a solution that will monitor various rates of these contaminants under the influence of dispersion and porosity of the formation.

Keywords: Modeling, Klebsiella Pneumonae transport, porosity and dispersion.

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1. Introduction

Microorganisms control the large quantity, variety and metabolic activity of the ocean and control significant biogeochemical pathways that involve the universal carbon cycle (Azam & Malfatti 2007). As a result, microbial processes are represented in mathematical models used to examine global carbon cycle– typical weather feedbacks and how aquatic eco - systems react to ecological gradients in e.g. temperature, stratification, and nutrient regimes (Fasham et al. 1990, Boyd & Doney 2002, Schmittner et al. 2005, Behrenfeld et al. 2006, Sarmiento & Gruber 2006). Groundwater chemistry is mostly a purpose of the mineral composition of the aquifer through which it flows. The Hydrochemical processes and hydro geochemistry of the groundwater vary spatially and temporally, depending on the geology and chemical characteristics of the aquifer. Apodaca, *et al*., (2002), Martinez & Bocanegra, (2002), have inferred that Hydrogeochemical processes such as dissolution, precipitation, ion-exchange processes and the residence time along the flow path control the chemical composition of groundwater. Abimbola, *et al*., (2002); Olatunji, *et al*., (2001), also established that geology plays a significant role in the chemistry of subsurface water. Moreso, the importance of mineral diagenesis in the geochemical evolution of groundwater has been elucidated by (Wicks, *et al.*, 1995; Back, *et al*., 1983; Plummer, 1977; Bredehoeft *et al*., 1983; Hendry & Schwartz, 1990). Studies by (Goldenberg *et al*., 1986; Jones *et al*., 1969; Drever, 1988; and Keller *et al*., 1991) have shown that when soluble minerals undergo digenetic reactions, they provide a medium for cationexchange reactions as well as present a significant influence on the geochemistry of an aquifer system Previous studies carried out in the area have tended to emphasize only the general water supply problems (Etu- Efeotor & Odigi, 1983; Amajor, 1986). Amadi, *et al*., (1989) assessed the hydro geochemistry of groundwater in parts of the Niger Delta. Etu-Efeotor, (1981); Udom, *et al*., (1999); Nwankwoala, *et al*., (2007), acknowledged that the groundwater quality in the area is rapidly weakening. Increase in inhabitants and rapid urbanization has made groundwater the main foundation of water supply, therefore, it is very important to understand the Hydrogeochemical processes that take position in the aquifer system. Abimbola, *et al*., (2002); Olatunji, *et al*., (2001); it also display reputable component of geology played that important role in the chemistry of subsurface water. Moreso, the consequence of mineral diagenesis in the geochemical volution of groundwater has been elucidated by (Wicks, *et al.*, 1995; Back, *et al*., 1983; Plummer, 1977; Bredehoeft *et al*., 1983; Hendry & Schwartz, 1990). Studies by (Goldenberg *et al*., 1986; Jones *et al*., 1969; Drever, 1988; and Keller *et al*., 1991) have revealed that when soluble minerals experience diagenetic reactions, they make available a intermediate for cationexchange reactions as well as present a momentous pressure on the geochemistry of an aquifer system. Earlier studies approved in the area of geochemistry emphasize only the general water supply problems (Etu- Efeotor & Odigi, 1983; Amajor, 1986). Amadi, *et al*., (1989) assessed the hydro geochemistry of groundwater in parts of the Niger Delta. Etu-Efeotor, (1981); Udom, *et al*., (1999); Nwankwoala, *et al*., (2007), acknowledged that the groundwater quality in the area is rapidly deteriorating. Increase in population and rapid urbanization has made groundwater the major source of water supply, hence, it is very essential to understand the Hydrogeochemical processes that take place in the aquifer system.

2. Theoretical background

The designs of ground water system in some part of deltaic s environment should made compulsion in those state location, this due to the high rate of pollution in the environment, this condition has generated several health challenges in the environments, furthermore the rate manmade activities are one of the paramount cause of unhealthy environment, these pollutions are through biological and industrial waste generation, but the focus of this study are pollutions from biological waste were microbes are generated thus migrate through the soil and water from one formation to another. Moreso, Looking at man made activities in area of huge oil exploration and production in Rivers state entirely area, an increase is require for fresh groundwater, because of the most important source of urban water supply for household and industrial uses. The increased rates of groundwater exploration are found to poses severe pressure in groundwater resources, almost every residence has a well. Also, most of the companies that produce chemical effluents discharge their wastes directly into the sea or creeks, without regard to the effects of the effluents on coastal aquifers and aquatic life. Rivers state precisely emuoha is located within the Niger Delta Basin of Southern Nigeria. The area lies stuck between latitudes 4030' and 5000'N and longitudes 6045' and 7030'E. The area is characterized by interchange wet and dry seasons (Iloeje, 1972). The rainy period starts in March and ends in October, with a peak in June and July. The rains are ushered in by the south west rain bearing winds which blow from the Atlantic Ocean into Nigeria. Within the rainy season, there is a short period of little or no rain called the 'August Break' which is commonly experienced in the month of August. The dry season begins in November and lasts till March, with a short Harmattan in December and early January. It is brought by the dry northeastern winds which blow across the Sahara desert into Nigeria; environmental influences from climatic condition express in this study are of several consequences resulting to the depositions of microbe's ion in soil and water environment. High rate pollution has developed several death traps in the study location; base on this condition mathematical model was fined suitable to express the rate klebsiella pneumonae migration in soil and water environment dispersion and porosity of the formation were one of the paramount parameters in the system that were considered, other variables were expressed, but they noted not to be influential much compared to dispersion and porosity of the soil in the study location, the study has significant role to play in the study location since it will definitely reduce high deposition of klebsiella pneumonae in the study area.

3. Governing equation

$$\phi \frac{\partial C}{\partial t} = \frac{\partial C}{\partial x}\left[\phi D \frac{\partial C}{\partial x}\right] - V \frac{\partial C}{\partial x} \qquad \text{..............................} \qquad (1)$$

The governing equation expressed here are modified to thoroughly monitor the transport of the system in soil and water environment , the system express dispersion and porosity of the formation as the paramount parameters that pressures the deposition of the microbes to ground water aquifers. High degrees of porosity are express in the system because it reflect the rate of dispersion in soil stratification, the system also reflect the deltaic nature of the formation under the influences of high degree of porosity variation in shallow aquifers, the study of dispersion through this mathematical equation will definitely streamline the functional imperativeness of the system as expressed in the governing equation. The structure of the governing equation will definitely showcase the relationship between the parameters in the system.

Applying Laplace transformation into equation (1) we have

$$\frac{\partial C}{\partial t} = SC_{(t)} - C_{(o)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\frac{\partial C}{\partial x} = SC_{(x)} - C_{(o)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad r(3)$$

$$\frac{\partial C}{\partial x} = SC_{(x)} - C_{(o)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$\frac{\partial C}{\partial x} = SC_{(x)} - C_{(o)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$C = C_{(o)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

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

$$\phi \left[SC_{(t)} = SC_{(x)} - C_{(o)} \right] - \phi D \left[SC_{(x)} = SC_{(x)} - C_{(x)} \right] - V\,C_{(o)} \quad \ldots\ldots \quad (7)$$

$$\phi\, SC_{(x)} - \phi S^{1}{}_{(x)} - C_{(o)} - \phi D\, SC_{(o)} - \phi D\, C_{(o)} - V\,C_{(o)} \quad \ldots\ldots\ldots\ldots\ldots\ldots$$

(8)

Considering the following boundary as:

at $t = 0,\ C^{1}{}_{(o)} = C_o = 0$ ……………………………. (9)

We have

$$C_{(x)} \left(\phi S - \phi S - \phi DS \right) = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

$$C_{(x)} \neq 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

Considering the boundary condition

at $t > 0,\ C(^{1}{}_{(o)} = C_{(o)} = C_o$ ……………………………..….

(11)

$$SC_{(t)} - \phi DS_{(x)} - VC_{(x)} = \phi\, SC_o + \phi D\, C_o + V\,C_o \quad \ldots\ldots\ldots\ldots \quad (12)$$

$$\left[\phi S - \phi D - V \right] C_{(x)} = \left[\phi\, S + \phi + \phi D \right] C_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

$$C_{(x)} = \frac{\phi S + \phi + \phi D}{\phi S - \phi DS + V} C_o \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (14)$$

Application of quadratic equation is to ensure that the variables express there various roles in the system the rate of dispersion of the microbes varies, this is base on the stratification of the formation in study are under the influence of geologic history, the application of quadratic function were found appropriate to ensure that the variables express there various function on how they influence the system on the migrations of the microbes at different formations of the soil. The applications of quadratic functions were finding suitable to discretize there various parameters under exponential condition. The application of theses method will definitely express the rate of klebsiella pneumonae in soil and water environment.

Applying quadratic expression, we have

$$S = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (15)$$

Where $a = \phi$, $b = \phi D$, $c = V$

$$S = \frac{-\phi D \pm \sqrt{\phi D^2 - 4\phi v}}{2\phi} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (16)$$

$$S_1 = \frac{\phi D - \sqrt{\phi D^2 - 4\phi v}}{2\phi} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (17)$$

$$S_2 = \frac{\phi D + \sqrt{\phi D^2 - 4\phi v}}{2\phi} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (18)$$

$$S_1 = \phi D + \frac{\left[\sqrt{\phi D^2 - 4\phi v}\right]}{2\phi} S_2 = \frac{\phi D - \sqrt{\phi D^2 - 4\phi v}}{2\phi} \ell^{\frac{\left[\phi D + \sqrt{\phi D^2 - 4\phi v}\right]}{2\phi}\frac{V}{t}} +$$

$$\frac{\left[-\phi D - \phi D\sqrt{\phi D^2 + 4\phi v}\right]}{2\phi} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (19)$$

Applying Laplace inverse of the equation, we obtain

$$C_t = \left[\frac{\phi}{t} + \phi + \phi D\right] \frac{\left[\phi D + \sqrt{\phi D^2 + 4\phi v}\right]}{2\phi} t + \ell^{\frac{\left[\phi D - \sqrt{-\phi D^2 + 4\phi v}\right]}{2\phi} t} \qquad \ldots\ldots\ldots \qquad (20)$$

But if $V = \frac{d}{t}$

$$\left[C[L,t] = \phi \Big/ d \Big/ t + \phi + \phi D \right] C_o \, \ell^{\frac{\left[\phi D + \sqrt{\phi D^2 + 4\phi v}\right]}{2\phi} \frac{d}{t}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

at $C(^1{}_{(o)} = t \neq 0$

Considering the following boundary condition as:

at $t = 0,\ C^1{}_{(o)} = 0 \quad C_o = 0$ ………………………..…. (22)

$$C_{(x)} = \left[\phi \big/ t + \phi + \phi D \right] C_o \left[\ell^{\frac{\left[\phi D + \sqrt{\phi D^2 + 4\phi v}\right]}{2\phi}} \right]^{\frac{d}{t}} + \frac{\left[\phi D \sqrt{\phi D^2 + 4\phi v}\right]}{2\phi} \frac{d}{t} \quad \ldots\ldots\ldots \quad (23)$$

at $C^1{}_{(o)} = t \neq 0$

Again $C_o = C_o$

This implies

$$C_o = [\phi + \phi D] C_o [1+1] \ i.e.\ 0 = [\phi + \phi D] 2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

$$\Rightarrow \quad \phi D + \phi D = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (25)$$

So that we have

$$C_{(x)} = \left[2 \phi \big/ t \right] C_o \, \ell^{\frac{\left[\phi D + \sqrt{\phi D^2 + 4\phi v}\right]}{2\phi} + \frac{\left[\phi D + \sqrt{\phi D^2 + 4\phi v}\right]}{2\phi}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (26)$$

However, $e^x + e^{-x} = 2Cosx$

Therefore, we have

$$C_{(x)} = \left[2\phi \big/ t \right] C_o \ Cos \frac{\left\lfloor \phi D + \sqrt{\phi D^2 + 4\phi v} \right\rfloor}{2\phi} t \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (26)$$

If $t = \frac{d}{V}$

$$C_{(x)} = \left[{}^{2\phi}\!/_{t}\right] C_o \; Cos \frac{\left\lfloor \phi D + \sqrt{\phi D^2 + 4\phi v} \right\rfloor}{2\phi} t \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (27)$$

$$C_{(x)} = \left[{}^{2\phi}\!/_{t}\right] C_o \; Cos \frac{\left\lfloor \phi D + \sqrt{\phi D^2 + 4\phi v} \right\rfloor}{2\phi} \frac{d}{V} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (28)$$

The expressed model is the final model equation that will determine the migration of klebsiella pneumonae influenced by dispersion and porosity in the study location. The rate of spread in the study area was established through risk assessment carried out. This concept was to find out the rate of microbial deposition and not the solutions to avoid the rate of spread in the study location. The ugly scourge was found to have developed into serious water pollution in the study area, but the rate of transport were not examined that determine the rate of dispersion of klebsiella pneumonae in the study location. Soil porosity is determined through the stratification of the formation under the influence of geologic history in the study area.

4. Conclusion

Dispersion of contaminants is determined by the stratification structure of the formation under the influence of geologic history. Stratification of the formation is determined through the rate of porosity under disintegration of the sediment from porous sedimentary rock formation. These conditions imply that the rate of dispersion of Klebsiella pneumonae in the soil formation, are very high based on these conditions the rate of such microbes become so paramount parameters contaminating groundwater aquifers. Deltaic nature of the formation expresses to an extent the rate of Klebsiella pneumonae under the influence of fast migration through the flow net in the porous medium. Moreso, accumulation of such contaminant may be found in lateritic soil reflecting low porosity in some conditions. This application reflects the variation of high rain intensities and degree of saturation under the influence of climatic conditions in the study location.

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