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Research article

PREDICTIVE MODEL TO MONITOR ENTEROBACTERIACEAE TRANSPORT IN UNCONFINED BED INFLUENCED BY AQUITARD RECHARGE IN COASTAL AREA OF AMADI-AMA, NIGER DELTA OF NIGERIA.

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Abstract

Enterobacteriaceae transport is generated from biological waste generation in the study location. These sources of pollution were found to be predominant through risk assessment carried out, including hydrological and desk study thus depositions of unconfined bed and aquitard. This result in detail also show the level of water quality and the rate of aquitard recharge influencing the unconfined bed, but the prevention of this solute were not recommended. High rate of enterobacteriaceae were found to deposit in the study location through thorough water quality investigation at different locations. This ugly scourge generated lots of outbreak of water, urinary tract infection and other water-related diseases in the study location, due to lack of permanent solution to this ugly scourge. Based on these factors, mathematical models were found appropriate to monitor the migration of enterobacteriaceae influenced by aquitard recharge in coastal area of Amadi-Ama. The influence of aquitard recharge is through high degree of saturation from high rain intensities, under the pressure of environmental influence expressing change in climatic condition. The aquitard recharge from this source influence the unconfined bed through the structural deposition of the strata from high degree of porosity and hydraulic conductivity in the formations. The study is imperative because mathematical approach will definitely in details express the rate of concentration at every formation to unconfined bed. Experts in this area of specialization will apply this conceptual framework in preventing enterobacteriaceae in aquiferous zones.

Keywords: Predictive model, enterobacteriaceae transport and unconfined bed.

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1. Introduction

The Niger Delta is situated at the southern end of Nigeria bordering the Atlantic Ocean. History told us that the proto delta developed in the northern part of the basin during the companion transgression and ended with the Daleocene transgression whereby the formation of the modern delta began during the Ecocene and it continued into present day where generate the third circle that the modern Niger Delta was formed. Meanwhile before now, the beginning deposition of the Niger Delta are the Albian sediment which consisted of stone over lain conformably by cenoniana and younger upper cretaceous sediments, these deposit were laid from during a predominantly marine depositional circle. Furthermore, the first cycle was concluded by a phase of folding, faulting and uplifting occurring in santonian time and which definitely affect particularly in general Abakaliki anticurrium (Kogbe, 1989 Eluozo,2013). The vertical distribution of groundwater are based on the interstices occupied partially by water and partially by air, in the zone of saturation, all interstices are filled with water under hydrostatic pressure. On most of the land masses of the earth, a single zone of aeration overlies a single zone of saturation and extends upward to the ground surface. In the zone of aeration, vadose water occurs. This general zone may be further subdivided into the soil water zone, the intermediate vadose zone, and the capillary zone. This is known to be surface atmospheric pressure and appears as the level at which water stand in a well permeating the aquifer (Todd, 2004 Eluozo, 2013).The static level of water in wells penetrating the zone of saturation is called the water table. The water table is often described as the subdued replica of the surface topography. It is generally higher under the hills and lowers under the valleys, and a contour map of the water table in any area may look the surface topography (Garg,,2004 2005).

Historically, pollution control measures have been focused more on point source pollution than on non-point sources, using control standards, regulatory enforcement, capital investment and management in industrial and municipal infrastructures (Justus, 2007). For example in Europe and North America, point source pollution has been greatly reduced (Daniel et al., 1998). This is because point pollution sources are easily identified, measured, collected and treated at the source. However, all over the world a large percentage of water pollution has been recognized as originating from non-point sources (Liu2002,2003). Unlike point sources, non-point sources are more difficult to measure and regulate, because they arise from various activities (i.e. agricultural production) dispersed over wide areas of land and variable in time and space due to effects of weather and the hydrologic cycle (Carpenter et al., 1998; Daniel et al., 1998, Eluozo 2013). Managing non-point sources of pollution in addition to being politically, economically, and socially difficult, is technically complex (Young et al., 1989 Justus, 2007). Pollution sources often are located over large geographic areas and are not readily identifiable. Therefore, assessment and quantification of pollution sources especially from non-point sources and their contribution to chemical loads to surface waters is an important aspect of remediation, monitoring, and control of water quality, especially for the lakes (Scheren et al., 2000 Eluozo 2013).

2. Theoretical background

The rate of microorganisms (enterobacteriaceae) is one of the commonest found in biological waste in the study location. The deposition of the species was found from some risk assessment carried out in the study location. These microbes deposited in soil and water environment migrate in the soil through the soil micropores to ground water table. This implies that such migration in soil with short period of time will be from one formation to another and to aquiferous zones. The study from hydrogeological studies expressed area where there deposition of aquitard recharge and unconfined bed in the study location. The deposition multi aquifers layers influenced by aquitard in the study area express several high degree of saturation under the influences of environmental influences. This is expressed through climatic conditions , this increase of high rain intensities, including geologic setting of the formation confirmed the formation also to deposit high degree of porosity and void ration, such condition assist the deposition shallow water table, such geologic condition expressed fast migration of the predominant enterobacteriaceae in the study area , the deposition of shallow aquifer influenced by aquitard increase the deposition of this type of microbial species, consequently generate water pollution within a short time , under this condition the results from risk assessment and hydrological studies only recommend some measures that may not be thorough solution to prevent this pollution sources thus reduces the consequences of the ugly scourge , the need for further solution were necessary to prevent this type of ground water pollution, base on the factors mathematical model were found appropriate to monitor the migration of the microbial species in the study area ,the derived solution were formulated base of the stated parameters that could cause the migration of the microbes to unconfined bed, the model were expressed through different mathematical symbols. this expressed governing equation will be derived to monitor the microbes in different formation to ground water aquifers further heal implication from this pollution are expressed. Human being medication, the most important family of bacteria is Enterobacteriaceae, which includes general species that develop well-defined diseases, as well as nosocomial infections. The members of this family are Gram-negative, rod-shaped, non-spore-forming facultative anaerobes that ferment glucose and other sugars, reduce nitrate to nitrite, and produce catalase but seldom oxidase. Most Enterobacteriaceae are components of the gastrointestinal flora of humans and animals, although many are also widespread in the environment. Furthermore, these bacteria can cause many different infections, such as septicemia, urinary tract infections, pneumonia, cholecystitis, cholangitis, peritonitis, wound infections, meningitis, and gastroenteritis, and they can give rise to sporadic infections or outbreaks.

3. Governing equation

$$T\frac{\partial^2 C}{\partial x^2} = -K \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

The governing equation that expressed the deposition of Enterobacteriaceae influenced by aquitard recharge is expressed mathematically above. Aquitard recharge is a geological formation of low permeability through which measurable leakage of groundwater can occur in a system of aquifer separated by aquitard or aquiclude, each aquifer may have a different piezometric or hydraulic head and may contain water of a different quality. These parameters are influenced also by other formation characteristics that express the deposition of aquitard in unconfined bed. The expressed governing equation considered these variables and denoted other dependent variable insignificant since the deposition of aquitard recharge are known to influenced by these dependent variables. These systems were formulated with only significant variables but may express other variables on the process of deriving the solution mathematically as a system.

$$\left[\frac{\partial C}{\partial x}\right] = \frac{CT\frac{1}{2} - C_1 - \frac{1}{2}}{\Delta x} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (2)$$

Where $\pm\ \frac{1}{2}$ refers to the Head Node I and 1 ± 1

There $\frac{\partial C}{\partial x}\ i+\frac{1}{2} = Ci+1-Ci\ and\ \left[\frac{\partial C}{\partial x}\right]C-\frac{1}{2} = \frac{C_1 - C - 1}{\Delta x}$ ……… (3)

Therefore, the second order differential term can be written as

$$\left[\frac{\partial C}{\partial x^2}\right] = \left[2\left[\frac{\partial C}{\frac{\partial x}{\partial x}}\right]\right] = \left[\frac{\partial C}{\partial x}\right] i+\frac{1}{2} - \frac{\left[\frac{\partial C}{\partial x}\right] i-\frac{1}{2}}{\Delta x} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (4)$$

Hence $\frac{\partial^2 C}{\partial x^2} = \frac{\partial C}{\partial x}\ i+\frac{1}{2} = Ci+1-Ci\ and\ \left[\frac{\partial C}{\partial x}\right]C-\frac{1}{2} = \frac{Ci+1-2Ci+Ci+1}{\Delta x^2}$ (5)

This implies that approximation on finite difference can be identified by the application of Taylor series. For a continuous single value and smooth function *f(x)* at Node I its value in the neighboured ± Δx, it can be given in terms of product of interval and gradient evaluated at Node

C = *(i – 1) - Δx* *C(1)* *Δx* *C (i + 1)*

$$\longleftarrow\!\!\longrightarrow\!\!\longleftarrow\!\!\longrightarrow$$

f(x) - Δx *f(x)* *(f(x) + Δx)*

From the application of finite difference, the discretizations of various parameters that influence the migration of enterobacteriaceae and aquitard recharge are monitored using this mathematical method. this application is applied to monitor the migration of the microbes influenced by aquitard recharge under linear condition precisely. The concentration of the microbe’s deposition and the velocity of aquitard recharge at different change of formation are expressed though the discretization in finite difference under the influence of the flow net. Subject to this relation, the direction of flow at different hydrostatic pressure expressed various velocity at different formation under the influence of hydraulic conductivity rate at every structural deposition of the soil.

The function of *f(x)* and corresponding head for Taylor series

That $f(x-\Delta x) \;=\; f(x)+\Delta x)\, f(x) + \dfrac{\Delta x^2}{2i} f^{11}(x)+........$ .... (6)

From figure (1) written the Taylor series for the equivalent function

$$Ci+1 \;= Ci + \Delta x\left[\frac{\partial C}{\partial xi}\right] + \frac{\Delta x^2}{2}\left[\frac{\partial^2 C}{\partial x}\right]_i + \frac{\Delta x^3}{6}\left[\frac{\partial^3 C}{\partial x^3}\right] + \frac{\Delta x^4}{24}\,\frac{\partial^4 C}{\partial x^4} \qquad \text{..............} \qquad (7)$$

$$C_o - 1\; Ci - \Delta x\left[\frac{\partial C}{\partial x}\right]_i + \frac{\Delta x}{2}\left[\frac{\partial^2 C}{\partial x^2}\right]_i - \frac{\Delta x^3}{6}\left[\frac{\partial^3 C}{\partial x^3}\right] + \frac{\Delta x^4}{24}\;....+ \qquad \text{..............} \qquad (8)$$

From the summation of equation (3) and (2)

$$Ci+1+\;Ci-1 = 2Ci + \Delta x^2\left[\frac{\partial^2 C}{\partial x^2}\right] + \frac{\Delta x}{12} + \left[\frac{\partial^4 C}{\partial x^4}\right]_i + \text{ [Higher order]}$$

Or it can be written as

$$\left[\frac{\partial^2 C}{\partial x^2}\right] = \frac{Ci+1-\;2Ci+Ci-1}{\Delta x^2} - \frac{\Delta x^2}{12}\left[\frac{\partial^4 C}{\partial x}\right]_i - \quad \text{[Higher order term]} \quad \text{..............} \qquad (9)$$

Further simplicity

$$\left[\frac{\partial^2 C}{\partial x^2}\right]_i = \frac{Ci+1-2Ci+Ci-1}{\Delta x^2} - \qquad \text{[Order of error } \Delta x^2\text{]}$$

Discarding the term since $\left[\frac{\partial^4 C}{\partial x^4}\right]$ can be

Assessed as follows:

$$\frac{\left[\frac{\partial^4 C}{\partial x^4}\right] = \left[\frac{\partial^3 C}{\partial x^3}\right]1+\frac{1}{2} - \left[\frac{\partial^3 C}{\partial x^3}\right]1-\frac{1}{2} = \left[\frac{\partial^2 C}{\partial x^2}\right]_{1+1}}{\Delta x^2} - \frac{\left[\frac{\partial^2 C}{\partial x^2}\right]_{1} - \left[\frac{\partial^2 C}{\partial x^2}\right] + \left[\frac{\partial^2 C}{\partial x^2}\right]_{1-1}}{\Delta x^2}$$

Or

$$\frac{\left[\frac{\partial^4 C}{\partial x^4}\right] = \left[\frac{\partial^2 C}{\partial x^2}\right]_{1+1} - 2\left[\frac{\partial^2 C}{\partial x^2}\right] + \left[\frac{\partial C}{\partial x^2}\right]_{1-1}}{(\Delta x)^2} \quad \ldots\ldots\ldots\ldots\ldots \quad (10)$$

The expression from equations (7) to (10) were the application of discretizing the concentrations with the stated mathematical method to showcase various concentrations at different formation under the influence of different directions of flows which detailed the rate of concentrations at different strata. Concentration from the surface without regeneration under linear condition may experience change of concentration as influenced by the direction of flow. Change of flow under the influence of variations of velocity can also be monitored using the application of the stated mathematical method. In line with this situation, the expression of aquitard recharge pressured by formation characterisitics were noted in the model concept using the final difference as expressed above.

Replacing *i* by 1+1 and 1-1 (respectively)

Therefore, with substitutions equation can be expressed in this form

$$\left[\frac{\partial^4 C}{\partial x^4}\right] = \frac{C_{1+2} - 2C_{1+1} - 2C_{1+1} + 4Ci - 2C_{1-1} + C_1 - 2C_{1-1} + C_{1-2}}{\Delta x^4}$$

Or it can also be expressed in this form

$$\left[\frac{\partial^4 C}{\partial x^4}\right] = \frac{C_{1+2} - 4C_{1-2} + 6C_{1-1} + C_{1-2}}{\Delta x^4} \quad \ldots\ldots\ldots\ldots\ldots \quad (11)$$

Considering the Node in the backward direction of the Node at which gradient is sought. This may be given as

$$\frac{\partial C}{\partial x} = \frac{C_1 - C_{1-1}}{\Delta x}$$

$$\left[\frac{\partial^2 C}{\partial x}\right] = \frac{\left[2\left[\frac{\partial^2 C}{\partial x}\right]\right]_1}{\partial x} = \left[\frac{\partial C}{\partial x}\right]_1 - \left[\frac{\partial C}{\partial x}\right]_{1-1} = \frac{C_1 - 2C_{1-1} + C_{1-2}}{\Delta x^2} \quad \ldots\ldots\ldots\ldots\ldots \quad (12)$$

And

$$\frac{\left[\frac{\partial^2 C}{\partial x^2}\right]_1 = \left[\frac{\partial^3 C}{\partial x^3}\right]_1 - \left[\frac{\partial^3 C}{\partial x^3}\right]_{1-1}}{\Delta x} \frac{\left[\frac{\partial^2 C}{\partial x^2}\right]_1 - 2\left[\frac{\partial^2 C}{\partial x^2}\right]_{1-1}\left[\frac{\partial^2 C}{\partial x^2}\right]_{1-2}}{\Delta x^2} \quad \ldots\ldots\ldots\ldots\ldots \quad (13)$$

From equation (12) $\left[\frac{\partial^2 C}{\partial x^2}\right] = \frac{C_1 - 2C_{1-1} + C_{1-2}}{\Delta x^2}$

Therefore $\left[\frac{\partial^2 C}{\partial x}\right]_{i-1} = \frac{C_{1-1} - 2C_{1-2} + C_{1-3}}{\Delta x^2}$ and $\left[\frac{\partial^2 C}{\partial x^2}\right]_{1-2}$

$$\frac{C_{1-2} - 2C_{1+1} - 2C_{1-3} + Ci - 4}{\Delta x^2} = C_{1-4}\ C_1 - 1 - 4_{(1-3)} + C_{1-4} \quad \ldots\ldots\ldots\ldots\ldots \quad (14)$$

Now scheme considering the Node in forward direction of the node at which gradient is sought, this may be expressed as $\left[\frac{\partial C}{\partial x}\right]_1 = \frac{C_{1+1} - C_1}{\Delta x}$

And

$$\left[\frac{\partial^2 C}{\partial x}\right] = \frac{\left[2\left[\frac{\partial^2 C}{\partial x}\right]\right]}{\partial x} = \left[\frac{\partial C}{\partial x}\right]_1 - \left[\frac{\partial C}{\partial x}\right]_{1-1} = \frac{C_1 - 2C_{1-1} + C_{1-2}}{\Delta x^2}$$

$$\frac{1}{\Delta x}\left[\frac{C_{1+2} - C_{1+1}}{\Delta x} - \frac{C_{1+1} + Ci}{\Delta x}\right] = \frac{C_{1+2} - 2C_{1+1} + C_1}{\Delta x^2} \quad \ldots\ldots\ldots\ldots\ldots \quad (15)$$

$$\frac{\frac{\partial^2 C}{\partial x^2} = -\left[\frac{\partial^3 C}{\partial x^3}\right]_1 = \left[\frac{\partial^2 C}{\partial x^2}\right]_{1+2}}{\Delta x} \frac{-2\left[\frac{\partial^2 C}{\partial x^2}\right]_{1+1} + \left[\frac{\partial^2 C}{\partial x}\right]_1}{\Delta x^2} \quad \ldots\ldots\ldots\ldots\ldots \quad (16)$$

From (16) $\left[\frac{\partial^2 C}{\partial x^2}\right] = \frac{C_{1+2} - 2C_{1-1} + C_1}{\Delta x^2}$

Therefore, $\left[\frac{\partial^2 C}{\partial x^2}\right]_{1+1} = \frac{C_{1+3} - 2C_{1+2} + C_{1+1}}{\Delta x^2}$ and $\left[\frac{\partial^2 C}{\partial x}\right] = \frac{C_{1+4} - 2C_{1+3} + C_{1-2}}{\Delta x^2}$

Replacing j by i+1 and i+2 respectively

Therefore, substituting the values equation (16) changes to

$$\left[\frac{\partial^4 C}{\partial x^4}\right]_i = \frac{1}{\Delta x^2}\left[\frac{C_{1+2} - 2C_{1+1} + C_{1-2}}{\Delta x^2}\left(\frac{C_{1+3} - 2C_{1+2} + C_{1+1}}{\Delta x^2}\right) + \frac{C_{1+3} + C_{1+2}}{\Delta x^2}\right] =$$

$$\frac{C_{1+4} - 4C_{1+3} + 6C_{1+2} - 4C_{1+1} + Ci}{(\Delta x)^4}$$

The following example shows that in enterobacteriaceae concentration to aquiferous zone, higher order term for both uniform and uniform migration through the flow path are insignificant and therefore can be discarded. The derived solution expressed the fractional degradation of enterobacteriaceae concentration and the rate of flow velocity with respect to change in distance under the influence of variation in concentration at different formations. This mathematical expression is to ensure that the behaviour of the microbes under linear condition including the velocity of transport at every formation is thoroughly noted. That implies that at every change in concentration, it will be noted at every formation. Such discretization of concentration and rate of velocity are expressed under the influence of homogeneous strata on vertical direction of flow in the system.

4. Concentration

The influence from aquitard recharge has been expressed to increase fast migration of the microbial spices in the study area. This recharge is influenced by several conditions which is at high pace in the study area. The deltaic natures of the formation showcase different environmental conditions that generate the deposition of enterobacteriaceae in Amadi-Ama environ. Since the study location deposits predominant of alluvium deposition that expressed homogeneous strata, it has been noted to play some roles on the rate of recharge penetrating unconfined bed influencing unconfined aquifer. Such depositions are influenced by some insignificant variables that were dominated by other variables; their existence can not be performed without those dependent variables such as void ratio and permeability. Therefore, the recharge influence on unconfined bed fast tracks the migration of enterobacteriaceae considering linear direction of a flow. Such flow path depositions are based on high degree of porosity that is pressured by high deposition of degree of saturation under the influence of high rain intensity in the deltaic environment. Such mathematical applications was found suitable to express in detail every rate of concentration of enterobacteriaceae including velocity of solute at every formation under the vertical direction of flow influenced by hydraulic conductivity and porosity of the formation. The model from these stated parameters have expressed the rate of migration of the microbes at every stratum as it is stated from the mathematical expression.

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