International Journal of Applied Chemical Sciences Research
Vol. 1, No. 8, September 2013, PP: 112 - 120, ISSN: 2328-2827 (Online)
Available online at http://www.ijacsr.com/

Research article

MODELING OF E.COLI TRANSPORT IN AQUIFEROUS ZONE INFLUENCED BY AQUITARD RECHARGE IN PORT HARCOURT, NIGER DELTA OF NIGERIA.

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Abstract

The rate of recharge in ground water aquifers and the migration of E.coli in the study location were thoroughly evaluated in the study location, the rate of microbial activities in deltaic environment in this study has been expressed, the rate of recharge in aquitard were found to influences the migration of E.coli in phreatic aquifers, the condition were found to increase the transport of E.coli in soil and water environment, these condition has definitely Develop lots of fast migration of E.coli through high degree of rain intensities in the study location, such environmental influences through climatic condition were found to be the most influential factors in the migration of E.coli pressured by aquitard in port Harcourt. To monitor the rate of E.coli under the influences of aquitard recharge, mathematical equations were found suitable to determine the rate of influences from aquitard recharge in the study location. The model were derived through the application of discrete system to ensure that all the variations are thoroughly captured in the system, the derived solutions considered every condition as expressed mathematically in the study area. The study is imperative because it assist experts to thorough determined the rate of migration under the influences of aquitard recharge in the study area.

Keywords; modeling of E.coli transport, aquiferous zone and aquitard recharge

1. Introduction

Groundwater has been described as the main source of potable water supply for domestic, industrial and agricultural uses in the southern part of Nigeria especially the Niger Delta, due to long retention time and natural filtration capacity of aquifers (Odukoya et al., 2002; Agbalagba et al., 2011; Ehirim and Ofor, 2011). Water that is safe for drinking, pleasant in taste, and suitable for domestic purposes is designated as potable water and must not contain any chemical or biological impurity (Horsfall and Spiff, 1998). Pollution of groundwater has gradually been on the increase especially in our cities with lots of industrial activities, population growth, poor sanitation, land use for commercial agriculture and other factors responsible for environmental degradation (Egila and Terhemen, 2004). The concentration of contaminants in the groundwater also depends on the level and type of elements introduced to it naturally or by human activities and distributed through the geological stratification of the area. It has been reported that petroleum refining contributes solid, liquid, and gaseous wastes in the environment (Ogbuagu, et al.,2011). The Niger Delta region of Nigeria is the crude oil and natural gas hub of Nigeria with several networks of product pipelines (both surface and subsurface) dotting the entire landscape which has created a social problem of vandalization of product pipelines and artisanal refining and the associated environmental hazards. Artisanal refining typically involves primitive illegal stills – often metal pipes and drums welded together – in which crude oil is boiled and the resultant fumes are collected, cooled and condensed in tanks to be used locally for lighting, energy or transport (UNEP, 2011, Gordon et al 2012).

Centrifuge modelling technique is being used to study many different aspects of soil behaviour Flow velocity in a centrifuge model at Ng will be N times faster compared to the prototype it represents. Consequently the scaling law for seepage velocity has been established as $m\ p\ v = N\ v$ (Schofield, 1980) and has been confirmed experimentally (Arulanandan et al., 1988). This scaling law for seepage velocity has been accepted and commonly used, but the question of whether it is the Darcy's permeability (hydraulic conductivity) or the hydraulic gradient that is a function of gravity has not been addressed properly. This issue was highlighted by Goodings (1979), who points out to the multiplicity of the concepts in scaling flow velocity. Butterfield (2000) and Dean (2001) also discussed this issue. Pokrovsky and Fyodorov (1968), Cargill and Ko (1983) , Tan and Scott (1985) and more recently Singh and Gupta (2000) are among many others who have considered permeability (k) to be directly proportional to gravity and hydraulic gradient (i) to be independent of gravity. While this explains why seepage velocity has a scaling law of N ($m\ p\ v = N\ v$), there is an alternative explanation for the increase of seepage velocity in a centrifuge. Schofield (1980), Hussaini et al. (1981), Goodings (1984), and Taylor (1987) have all suggested that permeability to be independent of gravity and it is the hydraulic gradient which has got a scaling factor of N. Since both sides of the explanation result in the same final answer $m\ p\ v = N\ v$ and it is the final seepage velocity that is considered important in many cases, the controversy has often been overlooked. In this technical note we attempt to resolve this controversy by using the energy gradient as the driving force on the pore fluid.

2. Theoretical background

The rate of ground water deposition in deltaic cannot be express without the climatic condition of an environment, environmental influence are one of the most paramount factor that influence ground water deposition under the influence of recharge in an environment, this include the degree of rain intensities and geologic history of soil and water in the environment, the rate of ground water recharge are express through the deposition of soil formation in the environment, the structure of the stratification of the study area are deltaic in nature, these has lots of environmental influence and such condition developing several variation in ground water deposition in depths including aquifer thickness. There is no hydrometeorological information that is readily available in the city of Port

Harcourt, but because of its proximity in both distance and latitude to Port Harcourt City, hydro meteorological parameters for Port Harcourt are generally adopted as predominant in most Port Harcourt environs. Rainfall in the area varies over a wide range in temporal context because of the occurrence of wet and dry season. The superficial soils in the area fall under the geomorphic classification of coastal Plain sands, although described as sands; they contain substantial amounts of clay at the upper horizon which impede effective drainage within the vadose zone. Some researchers refer to the coastal plain sands as the surface expression of the Geologic Benin Formation (Short and Stauble, 1967) but in the context of engineering applications, they are referred to as lateritic soils. They are rich in iron content. The bulk of groundwater in the Niger Delta is contained in very thick and extensive sediments of Benin Formation. The exploited aquifers including Bolo are derived from the Benin Formation. Based on geophysical and borehole data collected over the years, the Niger Delta hydro geological set up can be classified into: Impermeable/Semi permeable horizons from ground level to 10m below mean sea level.,, A permeable/gravel sand layer up to 80m below sea level., From 80m to 225m below sea level, the formation consists of a permeable sand/gravel layer with thin impermeable/semi permeable clay/silt layers. The water levels measured in the area fluctuate between 3m below ground level and 8.3m above sea level. In this aquifer more than 1500 wells are sunk in various part of Rivers State by private developers. The ground water levels respond to seasonal variations in rainfall and recharge. Groundwater level Monitoring at the site of the Bonny Export Terminal at the Port Harcourt Refinery revealed a lag in response time of a little over two months during the wet season; groundwater level is considerably close to the ground surface, thereby making groundwater highly vulnerable to pollution. In general the higher values are obtained from the north and the lower values in the southern part. The general direction of groundwater flow is southwards (Abam, 2011, Gordon et al 2012 Thusyanthan and .Madabhushi, 2003).

3. Governing Equation

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

The modified developed governing equations are from the expressed equation of [Rastogi 2007]. This expression was to ensure that the equation monitored the rate microbial contaminant and the same time determine the rate of aquitard influence on the transport of E.coli in port Harcourt, this conceptual development is to monitor the level of aquitard recharge influence on the transport of E.coli in soil and water environment, this development are confirmed through lots of hydrological studies carried out including water quality assessment on the study area, this results were not encouraging as most were found with lots of microbial activities deposited in ground water aquifers, the sources of drinking water and other utilization is from abstraction of ground water, they are found to deposit in shallow depths and the aquitard zone developed water such as hand dug well, the yield rate can sustain a small horse power pump especially when high rain intensities are very high, the recharge are always high under the influence of increase in degree of saturation. This implies that the rate of influence will definitely affect the migration of E.coli transport in soil and water environment, these governing equations were suitable to monitor the rate of E.coli transport in this direction.

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

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

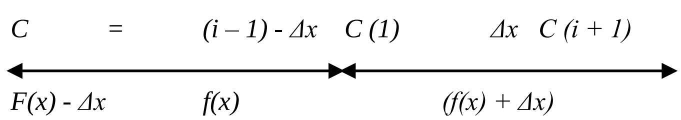
There $\frac{\partial C}{\partial x} i + \frac{1}{2} = Ci + 1 - Ci \; and \; \left[\frac{\partial C}{\partial x}\right] C - \frac{1}{2} = \frac{C_1 - C - 1}{\Delta x}$ ……… (3)

Therefore the second order differential term can be written as

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

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



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

The applications of this concept are to descretize the system in nodes in other to monitor the flow net under the influences of tortuosity in direction of ground water movement, the concept will thoroughly expresses the challenges experienced on such flow process in soil at different formation, such condition are found in the direction of flows under the influences of stratification of the formation modeling of E.coli transport under aquitard this is to determined the rate of migration and deposition in vadose zone influences on the transport system, the expression from this approach will monitor the migration sequentially at different stratum in the study location.

That $f(x - \Delta x) = f(x) + \Delta x) f(x) + \frac{\Delta x^2}{2i} f^{11}(x) + ...$ ………… (6)

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

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

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

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

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

Further simplicity

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

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

Assessed as follows:

$$\left[\frac{\partial^4 C}{\partial x^4}\right] = \frac{\left[\frac{\partial^3 C}{\partial x^3}\right]1+\;\frac{1}{2} - \left[\frac{\partial^3 C}{\partial x^3}\right]1-\;\frac{1}{2} = \left[\frac{\partial^2 C}{\partial x^2}\right]_{1+1}}{\Delta x^2} - \frac{\left[\frac{\partial^2 C}{\partial x^2}\right]_1 - \left[\frac{\partial^2 C}{\partial x^2}\right] + \left[\frac{\partial^2 C}{\partial x^2}\right]_{1-1}}{\Delta x^2}$$

Or

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

The expression from equation [6-10] displayed the derived solution in Taylor series this application were to monitor the system under discrete system, in Taylor series method, the system expresses the interaction of every variables and harmonized them in terms of their of functions and application, base on the behaviour of the recharge under the influence of soil structural deposition through the influence of geologic setting, the application of Taylor series in this phase of the derived solution were to ensure that the parameters expresses there function in all ramification in term of change of depth in soil formation, the influence of formation variation are predominant due to the deltaic nature of the formation, so the application of the mathematical concept expresses every rate of change under the influences of geological setting through formation characteristics in the study location

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

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

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

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

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

And

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

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 $\left[\frac{\partial^2 C}{\partial x^2}\right]_{1-2}$

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

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

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

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

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

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 $\left[\frac{\partial^2 C}{\partial x}\right] = \frac{C_{1+4} - 2C_{1+3} + C_{1-2}}{\Delta x^2}$ ………… (17)

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 E.coli concentration are changed in concentration with respect to change in distance to aquiferous zone, mathematically on the final derived model solution the higher order term for both uniform and uniform migration through the flow path are insignificant and therefore can be discarded. Applying this concept is to ensure that the rate of transport is base on the behaviour of the microbes, this concept was to monitor under the influence of change in variation of the soil and formation characteristics in the study area. The rate of monitoring this transport in discrete form is to ensure that every influence from the stratification of the formation are thoroughly expressed. This condition include change in concentration at different depth, the study streamline the rate of E.coli transport in the study location. The rate of recharge of aquitard were found to have been influenced by high degree of rain intensities, formation characteristics such as degree of saturation has been express from the derived model solution. The study is imperative because it captures all the condition on the influence of recharge including the variation pressures from the stratification of the soil in the study area.

4. Conclusion

Modeling of E.coli transport in aquiferous zone influenced by aquitard recharge has been mathematically expressed, the rate of aquitard recharge deposit within the silty formation, the yield rate are very low depending on the location, but when there is high rain intensities it increase the recharge rate thus influence from the activities of E.coli in the study area, the rate of deposition in the study location were considered in the system, this condition were integrated in the system as one on influential parameters in the system, the rate formation deposition were expressed at different condition base on the geological setting of the study location, Moreso the rate of E.coli deposition are influenced by the formation variable in the system, these condition were integrated base on the rate of influence considered, the expressed model derived through discrete of the system, the study is imperative because the concept will definitely monitor the rate of recharge and the level of migration sequentially to ground water aquifers in the study area.

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