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Research article

PREDICTIVE MODEL TO DETERMINE THE DEPOSITION OF NICKEL AND INHIBITION ON BACTERIOPHAGE TRANSPORT IN SHALLOW AQUIFERS IN COASTAL AREA OF BONNY, RIVERS STATE OF NIGERIA

Eluozo, S. N.

Subaka Nigeria Limited, Port Harcourt, Rivers State of Nigeria
Director and principal consultant Civil and Environmental Engineering, Research and Development
E-mail: Soloeluozo2013@hotmail.com
E-mail: solomoneluozo2000@yahoo.com

Abstract

Inhibition of nickel on bacteriophage transport in shallow aquifers has been evaluated. Shallow aquifers has been found to deposit high concentration of nickel through the industries, this is due to oil exploration in the study location. More so biological waste generated from the people living in the study area causes more harm to the people, this has caused hundreds of people suffering from different type of water related diseases, it is proper to find solutions to prevent poor sanitation and develop better option to prevent ground water contamination in the study area.To improve this condition, mathematical model were derived through the governing equation, the expressions were derived in phases,and this is to monitor the system by considering all the parameters that influence the exponential phase of bacteriophage in shallow aquifers. The formation under study is predominantly homogeneous and with slight heterogeneous deposition, the stratification in deltaic environment developed unconfined soil formation. This significant condition was considered in the system when the governing equation was formulated, the equation was derived and it developed models in accordance with behaviour of the microbes and other formation variables. Few models developed were integrated together, thus final expressed model was generated, and the model expressed all the parameters based on the behaviour of the microbes at different formation. The expressed model will definitely monitor the migration of bacteriophage in shallow aquifers, experts will find the model helpful, because it shows that the concentration of microbial deposition in ground water aquifers are in exponential state, these express the influence from constant regeneration of contaminant in shallow aquifers, but variation in nickel and bacteriophage in some condition will express inhibition from nickel, but can only experience degradation if there is no substrate deposition ,more so if there is high deposition of inhibitors in the study area.

Keywords: predictive model, nickel and bacteriophage transport and shallow aquifers

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1. Introduction

More than last few decades worsening of both the quality and quantity of groundwaterhas become a universal phenomenon, which will further make stronger demand for drinkingWater increases (World Bank report, 2006). Several severe cases of groundwater pollution with allusion to storm water infiltration have been documented worldwide (Lopes and Bender, 1998; Fischer, 2003). Few studies have also been documented nationally on groundwater with reference to main ions, trace elements and bacteriology (Arif 2007, Rahman et. al., 1997; Zubair, 1998, Liu and Li, 2005). However literatures aresoundless on theimpact of storm water permeation into groundwater.In recent years attention on the increasing ionic concentration of traces metals in groundwater as result of storm water infiltration has been studied by various workers (Ku et. al., 1992; Appleyard, 1993; Wild, 1994; Hathhorn and Yonge, 1995; Pitt, 1996; Lopes and Bander, 1998; Fisher, 2003). These have been ascribed to human intervention, propagation of industries and recent agriculture practices in urban areas where storm water flow recharges the aquifer system and thus degrading the water quality.Contaminants present in urban storm water include volatile organic compound, pesticides, nutrients, and trace elements (Fisher, 2003). This can originate at the land surface or in the atmosphere (Lopes and Bender, 1998Some constituents either volatize during storage or sorbs to the particulate matter (Mikkelsen et. al., 1996Arif 2007) and are not transported to the water table; however, are more persistent, and may threaten groundwater quality. Malmquist & Hard (1981) studied the impacts from sub surface infiltration at three sites in Sweden and concluded that storm water infiltration affects the groundwater quality to a small extent.

2. Theoretical background

Modeling the deposition of nickel was carried out considering the migration of bacteriophage in shallow aquifers, growth rate of this microbes were found rapidly increasing in the study location, this is under the influences of velocity, time, and distance on heavy metals and nickel concentration. To predict the effect nickel on the bacteriophage growth rate are base on the regeneration of the contaminant deposition in the coastal location, this condition can be expressed through the formation characteristics in the study area. To monitor the deposition and the rate of inhibition of nickel, the parameters that influenced the migration and deposition should be identified. This were done through hydrogeological studies, which was able to determine the deposition of aquiferous zone the depth and stratification of the formation, other geological settings were also expressed, based on these conditions stated above, mathematical expressions were developed. The equation formulated was based on the stated parameters that influenced the deposition and transport of nickel and bacteriophage in the study area. Bonny is suited on the Niger delta area where some multinationals companies that that carry out exploitation/exploration are based, the exploitation of the hydrocarbon generate lots of pollution in the area, these produce numerous contaminants from heavy metals and other pollutants. Nickel deposition was found in an environment where wastes are dumped indiscriminately, it is situated at industrial layout of the environments. The study area has few companies and waste generated are dumped indiscriminately in some area, while some are dumped at government approved sites, they are dumped indiscriminately without treatments before disposal, this generated wastes produce high percentage of industrial waste including biological waste from the people, waste are generated on a daily bases, the hazards generated from these wastes continue to deposit on the soil daily. Biological wastes generated from human settlement are in the same vein dumped, so the two types of waste are deposited in the study area daily without proper handling. The rate of hazards generated daily continue to increase and affect thousands of people that settle in the area causing thousand of illnesses and premature death yearly, this menace are rapidly increasing every day thus most people are ignorant of what is happening.

This source of pollution is serious concerns to environmental health and need to be thoroughly addressed, the rate of nickel and bacteriophage deposition were found from risk assessment carried out in the study area. These contaminants were confirmed to have deposited in the soil in a high percentage, due to constant dumping of these contaminants, the constant regeneration of these pollutants constantly accumulating on the soil. The study from hydrogeological point of view developed several variables that will always allow the deposition of these contaminants to migrate rapidly in soil and water environments. Results from hydro geological studies confirmed the study location to be deltaic environment, the soil formations are found to be deltaic in nature; these expressed other variables that influence the transport system of these two contaminants in the study area. The expressions from the dimension are through mathematical model, equations were formulated that will govern the deposition of nickel as inhibitors to bacteriophage growth rate in soil and water environment. The expressed equation considered the influential variable aid growth rate of bacteriophage in soil and water environment. The system considers the concentration from organic soil to ground water aquifer, formation characteristics influence on the deposition and migration were expressed in the system. The study area was found to be contaminated to a large extent these developments were found through the dispersions of nickel and bacteriophage in the soil formation. This implies that dispersion as a parameter will always play major role in the system. Therefore dispersionwas thoroughly expressed in the system; because the spread of the contaminants are through dispersions, the governing equation are stated below.

3. Governing Equation

$$C(x)\frac{\partial v(x)}{\partial t} - D\ V^2\frac{\partial C(x)}{\partial x} = \frac{V\partial C(x)}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$ML^{-2}\ T^{-2} \qquad ML^{-2}\ T^{-2}$$

The expressed governing equations to examine the migration of bacteriophage in the study area the developed equation express the bacteriophagestate in the formation, the generated equation were derived in stages base on exponential condition of the microbes, this express the behaviour under the pressure of the stratification of the formation. Exponential of the microbes are persuade by several parameters in soil and water surroundings, therefore the governing equation were derived bearing in mind the exponential state, this to ensure that the state of the microbes express in exponential are included in the system.

The equation (1) is non-homogenous process and can be written as

$$C_{(x)}\ \frac{\partial v(x)}{\partial t} - D_A v^2\ \frac{\partial c(x)}{\partial x} = \frac{V\partial c(x)}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

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The expressed equations represent the state of the microbes on heterogeneous structural deposition. The formation at this condition influences the transport system of the microbes, the expressed equation were able to see other behaviour of the microbes in region that developed heterogeneous soil formation. The expression were able to relate other parameters found to be influential in heterogamous and homogenous regions, the rate on fast migration of bacteriophageand its behaviour are influenced by formation characteristic of the soil.

If equation (1a) is time dependent only, the equation reduces to:

$$C_{(x)} \frac{\partial v(x)}{\partial t} = \frac{V \partial c(x)}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (3)$$

Considering when the system is at steady state, the above equation (2) can be rewritten as:

$$D_A v^2 \frac{\partial c(x)}{\partial x} = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (4)$$

The condition on the transport system were considered when the microbes are immobile in the system, this condition implies that there a tendency of the microbes accumulating or reducing in microbial concentration depending on the formation influence that increase the microbes or reduce it, the system express in such condition as zero.

For simplicity of solving equation (1), the following assumption is considered such as, let

$$C(x) \frac{\partial v(x)}{\partial t} = \beta \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (5a)$$

Therefore, substituting equation (5a) into equation (1) becomes

$$\frac{V \partial c(x)}{\partial t} + D_A v^2 \frac{\partial c(x)}{\partial x} = \beta \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (5b)$$

Equation (5b) can be rewritten as

$$\frac{V \partial c(x)}{\partial t} = - D_A v^2 \frac{\partial c(x)}{\partial x} + \beta \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (6)$$

The systems in the state express the behaviour of the microbes the reposition of the system, the accumulation of the microbes' to were it migrate experience dispersion, this condition implies that the contaminants at a certain level of transport are influence by high degree of porosity, this state resulted microbes dispersing to a large area in the environment, pollutant are a menace to ecological health because when they experience contamination rapidly due to formation influence on transport process, the microbial migration are spread to every part of the environments, under the pressure of dispersion, this situation contaminate the ground water aquifer to a very large extend , there the microbes on dispersion influences will always increase the contamination to every part within the environment, deltaic nature of the study location will always experience this sources of pollution due the geological setting.

Equation (6) obtained can be resolved using mathematical application. In this study expressed through mathematical tools known as separation of variable used in positive real number of λ^2 conditions. Thus, let

$$C(x) = Tx \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (7a)$$

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Since $C(x) \; = \; f(Tx)$ therefore, differentiating (7a) with respect to time and distance yields the following mathematical expression

$$\frac{\partial c(x)}{\partial x} \quad = \quad T^1 x \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (7b)$$

It can be obtained from separation of variables

$$\frac{\partial c(x)}{\partial x} \quad = \quad Tx^1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (7c)$$

Therefore, substituting equation (7b) and (7c) into equation (7a) and further expression by substituting equation (8) into the obtained equation yields

$$V\left(T^1 x\right) = D_A v^2 \; Tx^1 \; - \; Tx\frac{\partial v(x)}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (8)$$

Expanding further we get

$$VT^1 x \; = \; D_A v^2 \; Tx^1 \; - \; Tx\frac{\partial v(x)}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (9)$$

Dividing equation (8) by *Tx* we have

$$\frac{VT^1 x}{Tx} \; = \; D_A v^2 \frac{Tx^1}{Tx} \; - \; \frac{Tx}{Tx}\frac{\partial v(x)}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (10)$$

Thus, equation (10) can be written as

$$\frac{VT^1}{T} \; = \; D_A v^2 \frac{x^1}{x} \; = \; \frac{\partial v(x)}{\partial t} = \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (11)$$

Equation (11) having taking the shape of separate of variable application as a mathematical tools used in solving complex problems of this kind.

Solving equation (11) term by term, we have

$$\frac{VT^1}{T} \; = \; \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (12)$$

$$VT^1 \; = \; \lambda^2 T \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (13)$$

Applying the theory of Laplace transformation into equation (13) becomes

$$V(ST_{(s)} - T(o) \; - \; \lambda^2 T_{(s)} \; = \; 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (14)$$

Considering the boundary condition as follows

At T = 0

$$T(o) \; = \; C_1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (15)$$

Therefore, substituting the boundary condition of equation (15) with equation (14) becomes

$$VST_{(s)} - VC_1 - \lambda^2 T_{(s)} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

$$VST_{(s)} - VC_1 - \lambda^2 \; T_{(s)} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

$$VST_{(s)} - \lambda^2 T_{(s)} = VC_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

$$(Vs - \lambda^2)\, T_{(s)} = VC_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

Then $\frac{VC_1}{VS - \lambda^2}$ …………………. (20)

Therefore the Laplace inversion of equation (20) can be written as

$$T_{(t)} = VC_1 \, \ell \frac{\lambda^2}{V} t$$

From equation (11) we have

$$D_A V^2 \frac{x^1}{x^1} = \lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

Applying the same mathematical approach of Laplace transformation and considering the boundary condition at

$$X = 0$$

$$X(o) = C_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

Resolving the equation (21) by substituting the necessary boundary condition and using the mathematical equation as stated above given a general solution of

$$X_{(t)} = D_A V^2 C_2 \, \ell \frac{\lambda^2}{D_A v^2} t \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

The expression in (23) is a model generated with respect to distance travel on the transport process , the system at these phase were express to be in exponential stage in the study location, this expression shows the rate at which dispersion under velocity of transport influences the system, it also express its role on the exponential phase of the microbes in the model, the study area centered on waste dump environment, microbial concentration are always regenerating under the influence of constant indiscriminate dumping of waste and discharging of biological waste without treatment, so the state of exponential phase has experienced continuity but in the transport process also experience inhibition from nickel in some region of the formation in the study location

$$\frac{\partial v(x)}{\partial t} = \lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

Integrating the initial concentration for which $V = 0, \; V(o) = C_3$

$$SV_s - C_3 = \lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (25)$$

$$SV_s = \lambda^2 + C_3 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (26)$$

Making V_s the subject relation gives

$$V_s = \frac{\lambda^2 + C_3}{S} \qquad \text{......................} \qquad (27)$$

Using Laplace inverse we obtain

$$V_t = \lambda^2 + C_3$$

$$\lambda^2 = V_t - C_3 \qquad \text{......................} \qquad (28)$$

Therefore, from equation (20) where

$$T_{(t)} = VC_1 \ell^{\frac{\lambda^2}{V}t} \qquad \text{......................} \qquad (29)$$

The expressed model (29) displayed it reaction on relocation of the contaminants with respect to time, the concentration are monitored under the influence time. The system are under the situation when the period of migration from one region to the are determined by the structural stratification of the soil, this can be attributed to variation of the deposition of the micropoles in the soil formation, subject to this relation the behaviour from microbes under the influence of time are subject to void ratio variation that determine the degree of porosity. The expression in (29) will monitor the microbes under the influence of time through the degrees of void ratio and porosity in the formation. The rates of migrations within a short period of time are determined by the degree of these two parameters in the system.

Therefore, substituting equation (20) into equation (20) becomes

$$T_{(t)} = VC_1 \ell^{\frac{V_{(t)} - C_3}{V}t} \qquad \text{......................} \qquad (30)$$

Similarly, substituting equation (28) into equation (23) becomes

$$X_{(t)} = D_A V^2 C_2 \ell \frac{V_{(t)} - C_3}{D_A V^2} t \qquad \text{......................} \qquad (31)$$

But

$$C(x) = TX = VC_1 \ell^{\frac{V_{(t)} - C_3}{V}t}$$

Therefore

$$C_{(t)} = VC_1 \ell^{\frac{V_{(t)} - C_3}{V}t} \bullet D_A V^2 C_2 \ell^{\frac{V_{(t)} - C_3}{D_A V^2}t} \qquad \text{......................} \qquad (32)$$

But $V = \frac{\partial}{t}$

Therefore, $t = \frac{\partial}{V}$, thus equation (30) can be written as

$$C(x)_d = VC_1\,\ell^{\frac{V_t - C_3}{V} \bullet \frac{d}{V}} \bullet D_A V^2 C_2\,\ell^{\frac{V_{(t)} - C_3}{D_A V^2} \bullet \frac{d}{V}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (33)$$

The model in (33) is the ultimate model that express the exponential and rate inhibition from nickel phase condition of microbial transport in soil and water environment, exponential state were express mathematically to monitor bacteriophage behaviour on progressive condition, the developed governing equation were derived in phases, this is to descretize various overriding parameters, so that there functions on the microbial behaviour will be express. The express equation generated few models considering various phases, these depend on the behaviour of the microbes in there transport process. Theimportant parameters that develop exponential condition in microbes deposition were expressed in the system, thus the model that express different conditions are base on the influential parameters that may cause exponential function to the optimum level, the advantage of these model developed in phases were to ensure that the conditions that causes exponential migration of microbes while migrating to ground water aquifers are expressed, finally all the model were attached collectively developed the final model equation that will monitor bacteriophage in exponential phase in soil and water environment.

4. Conclusion

The developed equation that govern the migration of bacteriophage in homogeneous and slight heterogeneous unconfined aquifers has been expressed, modeling migration of bacteriophage growth rate in soil and water environment were formulated by considering the parameters that are important to the system. The migration on exponential phase of bacteriophage in soil and water environments depend on the strata deposition in the study location, the developed equation were expressed in phases, the model were in stages according to their behaviour and formation characteristics of the soil, the parameters that is dominant are considered so that it will express its functions to the maximum level in the system, this is to ensure that the behaviour of the microbes at each phase are full represented in the expressed model at every phase. The models were finally combined together to express the final model that will monitor the bacteriophage growth under the influence of nickel inhibition in unconfined aquifers.

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