Open Journal of Environmental Science and Development
Vol. 1, No. 1, November 2013, PP: 10 - 19
Available online at http://scitecpub.com/Journals.php

Research article

MODELING CHROMIUM TRANSPORT ON VERTICAL AND DISPERSIONS PHASE IN HOMOGENOUS PENETRATING UNCONFINED BED AT OBIO/AKPOR, RIVERS STATE OF NIGERIA

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Abstract

Modeling chromium transport on vertical and dispersion phase has been mathematically expressed. The concept is to monitor the migration process of chromium in dispersion phase and vertical column at different strata; this is to examine the rate of substance in penetrating unconfined bed. Such conditions were noted from previous risk assessment carried out on soil pollution, where chromium discovered to be a predominant depositor in the formation. The substances are deposited predominantly from manmade activities; constant regeneration rapidly increased the deposition at vertical condition including dispersion to other parts of the study location. Formation characteristics have also played its major role on rapid migrations; this is under the influence of hydraulic conductivity and constant increase of permeability in the strata. Such variables were considered in developing the governing equation. The derived model has established the rate of vertical and dispersion phase concentration in the strata, experts will find this model appropriate in determining the direction of transport including its rate of concentration at vertical and dispersion phase. This will enable them to know the dimension to prevent further pollution to other formations in unconfined bed regions in the study location.

Keywords: Modeling, chromium, transport, vertical dispersion and penetrating unconfined bd.

1. Introduction

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The Clean Water Act (CWA) requires states to assess state water bodies, usually via monitoring data, to determine if pollutants are present in sufficient quantities to prevent the waters from being utilized for their designated purposes (USEPA, 2002). When a water body, or section of a water body, is unable to be used for its designated purposes, it is considered to be impaired. Once a water body is classified as impaired and added to the 303(d) list, the CWA requires states to develop a Total Maximum Daily Load (TMDL) for the water body (USEPA, 2000). Development of TMDLs relies heavily on Computer models to identify pollutant contributors and to predict how different pollutant allocations in a watershed might affect the impaired water body. In Virginia, approximately 73% of impaired waters are impaired due to fecal coliforms (FC) (VDEQ, 2002). Current models used to develop bacterial TMDLs use laboratory-derived bacterial parameters that might be inappropriate for simulating field conditions. Once appropriate bacterial relationships are determined Pathogens are organisms, such as viruses and some bacteria, which are able to inflict damage on hosts that they infect (Madigan et al., 2000). Enumeration of pathogens is often time-consuming, technically intensive, and costly; therefore, pathogen presence is often estimated through the utilization of indicator organisms. Because FC and EC are found in the intestines of warm-blooded animals, their presence is indicative of fecal contamination. Potential sources of fecal contamination in water bodies include land-applied manure and sludge, manure from grazing animals, wildlife feces, combined sewer overflows, and failing septic systems. Youngblood-Myers (2001) investigated a potential alternative to testing waters for indicator organisms. Processes that are important to bacterial survival should be included in a bacterial nonpoint source model, including bacterial growth/die-off; sorption of bacteria to the soil matrix; partitioning of bacteria between water and sediment; and effects of management practices (Crane and Moore, 1985; Coyne and Blevins, 1995; Huysmans and Verstraete, 1993; Walker et al., 1990, Reddy et al., 1981). Mancini (1978) and Crane and Moore (1985) described three commonly observed patterns of coliform die-off: first-order decay; bacterial growth followed by first-order die-off; and die-off rate that changes with time. The first-order decay equation often used to describe bacterial die-off is expressed as Chick's Law (Crane and Moore, 1985) Modifications of Chick's Law by Mancini (1978), Polprasert et al. (1983), and Reddy et al. (1981) adjust the die-off rate constant for environmental impacts of temperature, solar radiation pH, and/or soil moisture content. Polprasert et al. (1983) researched the ability of waste stabilization ponds to reduce total and fecal coliform concentrations in wastewater, which was approximately the equivalent bacterial concentration of domestic waste, under both controlled (laboratory) and field conditions. Stephenson and Rychert (1982), Gary and Adams (1985), and Sherer et al. (1988) showed that disturbing bottom sediments resuspends fecal bacteria in overlying waters. Stephenson and Rychert's (1982) objective was to determine if a relationship existed between elevated EC concentrations in rangeland streams with bottom sediments. Coyne and Blevins (1995) used a pipette method for particle size analysis of aliquots of runoff samples from plots with vegetated filter strips (VFSs) that had turkey litter applied to them to determine if bacteria were associated preferentially with a specific particle size. Reddy et al. (1981) calculated retention coefficients (i.e., adsorption coefficients) for total coliforms and FC in river sediments, but these coefficients are not necessarily applicable for

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field soils. Huysmans and Verstraete (1993) found that *Escherichia coli* (EC) strains preferentially adhered to finer soils, as well; they specifically investigated EC adhesion to kaolinite, montmorillinite, and a clay loam soil.

2. Theoretical background

The deposition of chromium through manmade activities in some location of Obio/Akpor has been a source of concern to environmental health. The deposition of such substance was found to be predominant in some selected location where high concentration was observed. This pollution source has been a threat to deposited strata in the study area. Manmade activities were confirmed to have predominant production of chromium depositing in the formation, formation characteristics developed high level of dispersion from high deposited percentage of void ratio. Such condition found high accumulation of chromium depositing in some region of the formation. Homogeneous penetrating unconfined be has been observed to migrate the substance at vertical column and also dispersing to other environment, showing high rate of spread in the study location. Based on these factors, it is obvious that chromium deposition if not prevented from other spread might develop some serious ill health, because it has been confirmed to be responsible for ulcer and kidney damage. Depositing in penetrating unconfined bed implies that there should be a high accumulation rate in the formation that low permeability are observed, before depositing to penetrating unconfined bed. Furthermore, the expression of high deposition of the substance chromium implies that formation variations are influenced by geologic history as observed from previous risk assessment carried out. The study is to achieve the prevalent depositions of chromium penetrating unconfined bed, which will result to a serious hazard in aquiferous zones. Such development implies that permanent resolution to prevent such hazard in penetrating unconfined deposits should be thoroughly carried out. Based on these factors mathematical model were found appropriate to mathematically develop a model from developed governing equation, this is to ensure that the contaminant vertically deposited dispersion of chromium in some regions should be monitored. This will enable experts to determine the rate of concentration at different formations. This will enable the rate of concentration deposited at every formation observed to give an insight or predict further migration to ground water aquifers. Structural stratification has been noted to have played a major role on deposition of the substances. Such deposited strata has been structured from its geologic setting.

3. Governing equation

$$V\frac{\partial v}{\partial t} = U\frac{\partial v}{\partial x} = D\frac{\partial^2 v}{\partial y^2} + f(x, y) \qquad \text{..............................} \qquad (1)$$

The governing equation formulated from the expressed system is to develop a model that will monitor the dispersion of chromium, including its deposition on vertical condition. The study will in this dimension express various stages of influence that pressure the system resulting to high rate of hazards in penetrating unconfined bed. The expression

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in (1) will be derived with different mathematical approach to establish a model that will monitor the migration process on vertical and dispersion phase of the metal in penetrating unconfined bed.

$$V\frac{\partial v}{\partial t} + U\frac{\partial v}{\partial x} = f(x, y) \qquad \text{.............................. (2)}$$

Let $V = TX$

$$\frac{\partial v}{\partial t} = T^1 X \qquad \text{.............................. (3)}$$

$$\frac{\partial v}{\partial x} = TX^1 \qquad \text{.............................. (4)}$$

$$VT^1 X + UTX^1 = f \qquad \text{.............................. (5)}$$

$$V\frac{T^1}{T} + U\frac{X^1}{X} = f \qquad \text{...................... (6)}$$

$$V\frac{T^1}{T} = f \qquad \text{.............................. (7)}$$

$$U\frac{X^1}{X} = f \qquad \text{.............................. (8)}$$

From (7), $V\frac{dT^1}{T} = fdt$ .... (9)

$$\int\frac{dT^1}{T} = \int\frac{f}{\phi}dt \qquad \text{.............................. (10)}$$

$$\text{In } T = \frac{f}{\phi}t + a_1 \qquad \text{.............................. (11)}$$

$$T = \ell^{\frac{f}{V}t + a_1} \qquad \text{.............................. (12)}$$

$$T = C_1\ell^{\frac{f}{\phi}t} \qquad \text{.............................. (13)}$$

$$U\frac{dX^1}{X} = fdx \qquad \text{.............................. (14)}$$

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$$\int \frac{dX}{X} = \int \frac{f}{u} dx \quad \text{.............................. (15)}$$

$$\text{In } X = \frac{f}{u} x + a_2 \quad \text{.............................. (16)}$$

$$X = \ell^{\frac{f}{u} x + a_2} \quad \text{.............................. (17)}$$

$$X = C_2 \ell^{\frac{f}{u} x} \quad \text{.............................. (18)}$$

But $V = TX$

$$V_1 = C_1 \ell^{\frac{f}{V} t} \bullet C_2 \ell^{\frac{f}{u} x} \quad \text{.............................. (19)}$$

$$V_1 = C_1 C_2 \ell^{\left(\frac{t}{V} + \frac{x}{u}\right) f} \quad \text{.............................. (20)}$$

$$\boxed{V_1 = C \ell^{\left(\frac{t}{\phi} + \frac{x}{u}\right) f}} \quad \text{.............................. (21)}$$

The expression in (21) established a progressive phase of the transport system where high rate of concentration are deposited. Subject to this relation, it is obvious that the concentration is in progressive condition under the influence of high rate of permeability deposited in the formation. Such condition can be noted as initial concentration of the pollutant, based on the expressed model in (21) under the influence of permeability deposited in the strata. The developed model in (21) has showcased the level of rapid migration to the penetrating unconfined aquifer in the study area.

$$V \frac{\partial v_2}{\partial t} = D \frac{\partial^2 v_2}{\partial y^2} \quad \text{.............................. (22)}$$

Let $V = TY$

$$\frac{\partial v}{\partial t} = T^1 Y \quad \text{.............................. (23)}$$

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$$\frac{\partial^2 v}{\partial y^2} = TY^{11} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

$$VT^1Y = DTY^{11} = \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (25)$$

Let $$V\frac{T^1}{T} = D\frac{Y^{11}}{Y} = -\lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (26)$$

$$\int \frac{dT}{T} = \int \frac{-\lambda^2}{\phi} dt \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (27)$$

$$\text{In } T = \frac{-\lambda^2}{V} t + a_3 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (28)$$

$$T = \ell^{\frac{-\lambda^2}{V} + a_3} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

$$T = C_3 \ell^{\frac{-\lambda^2}{V} t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

$$D\frac{Y^{11}}{Y} = -\lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (31)$$

$$\frac{d^2 y}{dy^2} + \frac{\lambda^2}{D} Y = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (32)$$

Auxiliary equation is

$$m^2 + \frac{\lambda^2}{D} Y = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (33)$$

$$m \pm i \frac{\lambda}{\sqrt{D}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (34)$$

$$Y = A\,Cos \frac{\lambda}{\sqrt{D}} y + B\,Sin \frac{\lambda}{\sqrt{D}} y \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (35)$$

Combine (6) and (7), we have;

$$V_2 = TY$$

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$$V_2 = C_3 \ell^{\frac{-\lambda^2}{V}t} \left(A Cos \frac{\lambda}{\sqrt{D}} y + A Sin \frac{\lambda}{\sqrt{D}} y \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (36)$$

The developed model in (36) showcased an interaction with change in stratification of the strata that expressed migration process of the contaminant under the influence of constant migration. when there is no level of inhibition in the migration process of chromium. Formation influence such as high percentage of void ratio and porosity develop the migration condition of chromium under the influence of nonreactive substances in the region that would have inhibit the heavy metal, maintaining constant concentration are under the influence of the stated parameter. This expression in (36) established such condition to be involved in the transport system of the contaminant as it is expressed in the model stated above.

Considering

$$U \frac{\partial v_3}{\partial x} = D \frac{\partial^2 v_3}{\partial y^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (37)$$

Let $V_3 = XY$

$$\frac{\partial v_3}{\partial x} = X^1 Y \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (38)$$

$$\frac{\partial^2 v_3}{\partial y^2} = XY^{11} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (39)$$

$$UX^1 Y = DXY^{11} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (40)$$

$$U \frac{X^1}{X} = D \frac{Y^{11}}{Y} = \rho^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (41)$$

$$U \frac{X^1}{X} = \rho^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (42)$$

$$\frac{X^1}{X} = \frac{\rho^2}{U} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (43)$$

In $X = \frac{\rho^2}{U} x + a_4$ ………………………….. (44)

i.e. $X = \ell^{\frac{\rho^2}{U} x + a_4}$ ………………………….. (45)

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$$X = C_4 \ell^{\frac{\rho^2}{U}x} \quad \text{..............................} \quad (46)$$

$$D\frac{Y^{11}}{Y} = \rho^2 \quad \text{..............................} \quad (47)$$

$$\frac{d^2y}{dy} - \frac{\rho^2}{D}Y = 0 \quad \text{..............................} \quad (48)$$

Auxiliary equation is

$$m^2 - \frac{\rho^2}{D} = 0 \quad \text{..............................} \quad (49)$$

$$m = \pm \frac{\rho}{\sqrt{D}} \quad \text{..............................} \quad (50)$$

$$Y = D\ell^{\frac{\rho}{\sqrt{D}}y} + E\ell^{\frac{-\rho}{\sqrt{D}}y} \quad \text{..............................} \quad (51)$$

Combining (46) and (51), yield;

$$V_3 = XY$$

i.e.

$$\boxed{V_3 = C_4\ell^{\frac{\rho^2}{U}x}\left(D\ell^{\frac{\rho}{\sqrt{D}}y} + E\ell^{\frac{-\rho}{\sqrt{D}}y}\right)} \quad \text{..................} \quad (52)$$

Combining (5), (8) and (11), yield;

$$V(x,y) = V_1 + V_2 + V_3$$

$$V(x,y) = C\ell^{\left(\frac{t}{V}+\frac{x}{u}\right)f} + C_3\ell^{\frac{-\lambda^2}{V}t}\left(ACos\frac{\lambda}{\sqrt{D}}y + ASin\frac{\lambda}{\sqrt{D}}y\right)$$

$$V_3 = C_4\ell^{\frac{\rho^2}{U}x}\left(D\ell^{\frac{\rho}{\sqrt{D}}y} + E\ell^{\frac{-\rho}{\sqrt{D}}y}\right) \quad \text{..............................} \quad (53)$$

The vertical deposition and the dispersion rate of chromium were discovered in the study area through risk assessment. Such point of depositios no doubt is influenced by change in concentration with respect to change in depth under the law of plug flow. Formation influence play a major role in the condition of migration process,

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because the structural setting of the strata depends on this integration of the porous rock that developed different bed of the soil matrix thus producing variation of void ratio, porosity and permeability of the formations. Penetrating unconfined bed may also be influenced by environmental influence through climatic condition, generating high rain intensities in the study location. Such deltaic influence increases the migration process through intake of fluid flow that increased ground water tables in the study area. The process rapidly transport and disperse chromium in the study location.

4. Conclusion

Vertical condition and dispersion phase of chromium migrations in penetrating unconfined bed has been mathematically expressed. The system derived the force of monitoring the rate of migration under the influence of structural conditions through its geologic setting. Formation characteristics, no doubt were defined to have played its roles as migration process pressured to obey the structural setting of the strata. Such condition approve a tremendous influence of formation characteristics as reflected in the migration process of chromium through vertical and dispersion phase condition of the system.

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