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Research article

MODELING FLUID FLOW IN A VERTICAL COLUMN INFLUENCED BY PHOSPHORUS DEPOSITION IN ORGANIC AND LATERITIC SOIL IN PORT HARCOURT METROPOLIS

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Abstract

The deposition fluid has been expressed on the influences of substrate deposition phosphorus in organic and lateritic soil , the study were develop to monitor the fluid movement in vertical column , the conceptual framework has see the level Darcy law has showcase lot of fluid flow rate in soil at different dimensions, but under analytical concept few experts if there any proof result that been developed to express the rate of fluid flow under the influences permeability through a hydraulic gradient principle, although the sample formation monitored in this study are not aquiferous zone but the deposition of phosphorus and the geological setting influences the rate of fluid deposition and its variation within the sample formation under study, the conceptualized framework find mathematical modeling approach to monitor the depositions of fluid movement and substrate phosphorous in vertical column, the derived solution from governing equation expressed various mathematical approach that generated better solution in the study area.

Keywords: modeling fluid flow, phosphorous deposition, organic and lateritic soil

1. Introduction

Grain size, shape, and packing are characteristics of granular porous media that have a significant effect on groundwater flow, affecting both porosity and permeability. Hubbert [1940] determined that if uniform spheres are uniformly packed, porosity is not a function of grain diameter but permeability is a function of the square of the grain diameter. However, natural sediment does not consist of uniform grains and packing; it contains mixtures of finer and coarser grains of irregular shapes and complex packing arrangements. Nevertheless, the effects on porosity and permeability when sediment is not uniform in size and packing have been extensively explored but the effects on porosity and permeability when sediment is not uniform in shape needs to be explore further. Laboratory and field experiments have verified that grain size and packing affect porosity and permeability in unconsolidated clastic sediment [Freeze and Cherry, 1979; marsily, 1986; Domenico and Schwartz, 1990]. Research has also been conducted on estimating hydraulic parameters, porosity and permeability, and the sediment parameters, grain size and packing. Koltermann and Gorelick [1995] worked to improve the knowledge of these relationships by modifying previous petro physical models to more accurately predict the permeability of sediment mixtures. Kamann [2004] expanded on the work of Koltermann and Gorelick [1995] to account for five possible types of packing rather than the two types of packing upon which their fractional packing model was based. He took porosity and permeability Measurements on model bimodal sediment mixtures that varied in the volume fraction of finer grains, which he compared with predicted values. In keeping with Koltermann and Gorelick [1995], Kamann [2004] also modeled the porosity and permeability of bimodal sediment mixtures to address the effect of the volume fraction of fines. As the volume fraction of fines increases within a sediment mixture, porosity changes as the packing of the mixture changes. A porosity minimum occurs when the volume of the finer component equals the pore volume of the coarser component. Kaman's [2004] used spherical grains to model poorly-sorted sands and sandy gravels. Spherical glass beads and marbles were used to represent fine sand, medium sand, coarse sand and pebble grain sizes. Kamann [2004] chose to use spherical grains to eliminate variations in shape. He assumed that the bimodal sediment mixtures of spherical glass beads and marbles provided an approximation of natural sediment. Con rad [2006] focused specifically on measurements taken at small support scales using the air-based method of determining permeability on mixtures of spherical grains. He revised the permeability procedures, improved the air-based permeameter correction model developed by Kamann [2004], replicated and improved upon the permeability measurements taken by Kamann [2004], and further confirmed the applicability of the petro physical model for permeability. The research conducted by Koltermann and Gorelick [1995], Kamann [2004] and Conrad 2006] explored the effect of grain size and packing on porosity and permeability. The focus of this research will explore the effect of grain size, shape, and packing on porosity and permeability by using bimodal mixtures of natural sediment This study will continue the work of Kamann [2004] and Conrad [2006] by replacing spherical glass beads and marbles with natural sand grains and pebbles to reexamine the effect of the volume fraction of fines on porosity and permeability. The goals of this study are to (1) measure porosity and permeability for mixtures of natural sediment that vary by percentages of the volume fraction of finer grains, (2) to evaluate if the model created by Kamann [2004] based on spherical grains is accurate for natural sediment grains and (3) to improve the confidence of estimating porosity and permeability [Peter 2005].

Soil and groundwater contamination remains a threat to public health and the environment despite decades of research. Numerous remediation technologies including bioremediation, thermal treatment, soil vapor extraction (SVE), zero-valent iron (ZVI), and in situ chemical oxidation (ISCO) have been developed over the past 30 years. Bioremediation is a cost-effective and simple remediation process for the degradation of contaminants such as benzene, toluene, ethylbenzene, and xylenes (BTEX) [Kao et al., 2010; Nebe et al., 2009]. However, bioremediation is constrained by the available microbial community and by its degradation capacity in a given environment [Steliga et al., 2009]. Due to the complexities of extending laboratory results to the field [Stenuit et al., 2008], the actual rate of degradation as a result of bioremediation is slow relative to other treatments and often relies on natural attenuation, where no treatment is applied and the contaminant degrades naturally (Kao et al., 2010). Bioremediation, SVE, and ZVI degrade or constrain a narrow range of contaminants and are generally unable to treat sorbed contaminants and dense Nonaqueous phase liquids (DNAPLs) due to mass transfer limitations [Watts and Teel, 2006; Watts, 1998]. Persulfate is typically activated to promote contaminant degradation (Liang et al., 2004; aldemer et al., 2007; Furman et al., 2009). The activating agents include: ironchelated activation [Liang et al., 2004], base activation [Furman et al., 2009], and organic activation [Ahmad, 2010].

2. Theoretical Background

Fluid flow in soil are observed in different dimension it is either in capillarity rise base on degree of saturation of ground water movement aquitard to confined bed. The rate of fluid deposition and its movement are determined by several condition, several experts have try to model fluid flow either in saturated or unsaturated zone, theses studies are done by several researchers in different approach, base on this condition it's imperative to monitor the deposition of fluid and it movement under the influences of phosphorus in organic and lateritic soil in port Harcourt metropolis, the rate of microbes are found to deposit high degree in the study location, the deposition of microelement phosphorus are found to develop high rate of microbial concentration, this has been investigated in the soil formation to have deposited at high degree in lateritic and organic soil formation in the study location. The study of fluid flow rate in soil and water environment has stream line, there are various influences on the increase of microbial deposition through the in organic and lateritic soil formation. in the study area, the conceptual framework on this study is to monitor the rate of flow in a vertical column on the influence from the deposition of phosphorus in movement of fluid flow within the intercedes , the deposition of these substrate in organic and lateritic soil migrate from the organic soil through the rate of permeability and porosity of the soil at high deposited degree in the study area. In these conditions the design of the conceptual frame work is to ensure that every influences on increase of contaminants including the deposited degree of permeability and porosity are observed. To monitor fluid flow and influences of phosphorus in organic and lateritic soil

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3. Governing Equation

$$q\frac{h}{\partial z} = K\frac{hA}{L}\frac{dh}{dz} - \frac{dh}{dt} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\frac{dh}{dz} = S^1 h(z) - Sh(o) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\frac{dh}{dz} = S^1 h(z) - Sh(o) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$\frac{dh}{dt} = S^1 h(t) - Sh(o) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$S^1 h(z) - (z) - q\left[S^1(z) - S^1 h(o)\right] - K\frac{hA}{L} - a\left[S^1 h(t) - Sh(t)\right] \quad \ldots\ldots\ldots \quad (5)$$

$$S^1(z) - h(o) = qS^1 h(o) - qho \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

$$K\frac{hA}{L}h(z) - K\frac{hA}{L}S\, h(o) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

$$dh(z) - S\, h(o) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

Let $h(o) = 0$

We have

$$S^1(t) - qS^1 h(o) - K\frac{hA}{L}S^1 h(z) - ah(t) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

$$h(z) = \frac{1}{S}\left[qS^1 h(t) - K\frac{hA}{L}S^1 - \alpha S^1(t)\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

$$h(z) = \frac{1}{S^1}\left[qS^1 h(t) - K\frac{hA}{L}S^1 - \alpha(t)\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

$$\frac{h^1(z) = qS^1 h(t) - K\frac{hA}{L}h(z) - \alpha S^1}{S} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

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$$h(z) = q^2 h(t) - K\frac{hA}{L} h^1(z) - \alpha h^1(t) \quad \ldots\ldots\ldots\ldots \quad (13)$$

$$h(z) = q^2 S^1 h(t) = \frac{K\frac{hA}{L} h^1(z)\ \alpha h^1(t)}{S} \quad \ldots\ldots\ldots\ldots \quad (14)$$

$$h(z) = \left[q^2 - K\frac{hA}{L} - \alpha\right] h(t) \quad \ldots\ldots\ldots\ldots \quad (15)$$

$$S^1 h(z) = \left[q^2 - K\frac{hA}{L} - \alpha\right] h(t) \quad \ldots\ldots\ldots\ldots \quad (16)$$

$$h(z) = \frac{S^1 h(t)}{qS^1 - K\frac{hA}{L} - \alpha} \quad \ldots\ldots\ldots\ldots \quad (17)$$

$$\boxed{h(z) = \frac{S^1(z)}{qS^1 - K\frac{hA}{L} - \alpha S^1}} \quad \ldots\ldots\ldots\ldots \quad (18)$$

Furthermore, considering the boundary condition, we have the following

At $t = 0\ h^1(o) = h(o) = 0$

$$qS^1 - h(z) - K\frac{hA}{L} h(z) - \alpha S^t h(t) = 0 \quad \ldots\ldots\ldots\ldots \quad (19)$$

$$h(z) = \frac{0}{q - K\frac{hAS}{L} - \alpha S} \quad \ldots\ldots\ldots\ldots \quad (20)$$

Considering the following boundary condition when

At $t = 0\ h^1(o) = h(o) = 0$

Apply the condition into this equation

$$qS^1 - h(z) - qho - q - K\frac{hA}{L} h(z) - K\frac{hA}{L} ho - h(z) - \alpha h(t) - \alpha ho + h(t) \quad \ldots\ldots \quad (21)$$

$$q(z) - K\frac{hA}{L}h(z) = qS\,h(o)\ \ qho - \ K\frac{hA}{L}ho - h(z) - \alpha\,ho \quad \ldots\ldots\ldots\ldots \tag{22}$$

$$h(z) = \left[qs + q + K\frac{hA}{L} + \alpha \right] ho \quad \ldots\ldots\ldots\ldots \tag{23}$$

$$h(z) = qs - q - K\frac{hA}{L} - \alpha\ \ ho \quad \ldots\ldots\ldots\ldots \tag{24}$$

$$h(z) = \frac{\left[qs - q - K\frac{hA}{L} - \alpha \right] ho}{qs - \ K\frac{hA}{L} - \alpha} \quad \ldots\ldots\ldots\ldots \tag{25}$$

Applying quadratic equation to determine denominator for the equation

$$qs - K\frac{hA}{L} - \alpha = 0 \quad \ldots\ldots\ldots\ldots \tag{26}$$

$$S = \frac{-b \pm \sqrt{b^2 - 4ac}}{2ah} \quad \ldots\ldots\ldots\ldots \tag{27}$$

Where $\alpha = q, b = K\frac{hA}{L}, -\ c = \alpha$

Application of quadratic functions that determine denominator for the equation, this condition was streamline the relationship of the parameters in the system, the detail functions of these parameters in system are observed to establish within the quadratic condition in the system, the functions are within the formation characteristics in the system, there the application of quadratic function are base on the developed system.

$$S = \frac{-K\frac{hA}{L} \pm \sqrt{K\frac{hA}{L}^2 - 4q\alpha ho}}{2q} \quad \ldots\ldots\ldots\ldots \tag{28}$$

$$\left[S_1\ \frac{-K\frac{hA}{L} + \sqrt{K\frac{hA}{L}^2 - 4q\alpha ho}}{2q} \right] \left[S_2\ \frac{+K\frac{hA}{L} - \sqrt{K\frac{hA}{L}^2 - 4q\alpha ho}}{2q} \right]$$

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$$\ell^{\left[\frac{K\frac{hA}{L}-4q\alpha ho}{2q}\right]t^2}\left[K\frac{hA}{L}-\frac{\sqrt{K\frac{hA^2}{L}-4q\alpha ho}}{2q}\right]t \quad \ldots\ldots\ldots\ldots \quad (29)$$

The Laplace inverse of the equation yield

$$h(z)=\left[\frac{q}{z}+q+K\frac{hA}{L}\right]ho\;\ell^{\left[K\frac{hA}{L}+\frac{\sqrt{K\frac{hA^2}{L}-4q\alpha ho}}{2q}\right]t} \quad \ldots\ldots\ldots \quad (30)$$

$$h(t)=\left[\frac{K\frac{hA}{L}}{t^2}ho\right]\left[K\frac{hA}{L}+\frac{\sqrt{K\frac{hA^2}{L}-4q\alpha ho}}{2q}\right]\ell^{\left[K\frac{hA}{L}\frac{\sqrt{K\frac{hA^2}{L}-4q\alpha ho}}{2q}\right]}$$

$$\ell^{\left[K\frac{hA}{L}\frac{\sqrt{K\frac{hA^2}{L}-4q\alpha ho}}{2q}\right]t-\left[K\frac{hA}{L}\frac{\sqrt{K\frac{hA^2}{L}-4q\alpha ho}}{2q}\right]t} \quad \ldots\ldots\ldots\ldots \quad (31)$$

At this point $ho=0 \quad t\neq 0$

For equation (30) at $t=0\ h(o)=\ h(o)$, we have

$$ho=\ (q+K\frac{hA^2}{L}-\alpha)ho\ (1-1-1)=0=(q-K\frac{hA}{L}-\alpha)$$

Hence $q-K\frac{hA}{L}-\alpha=0$

Equation (31) becomes

$$h(z)=ho\left[\frac{q}{t}+2\right]\left[K\frac{hA}{L}+\frac{\sqrt{K\frac{hA^2}{L}-4q\alpha ho}}{2q}\right]t\left[K\frac{hA}{L}\frac{\sqrt{K\frac{hA^2}{L}-4q\alpha ho}}{2q}\right] \ldots\ldots \quad (32)$$

We recall that $e^{x}+e^{-x}=2Cos\,x$, so that equation (32) can be expressed as:

$$h(z) = \left[K\frac{hA}{L} + 2 \right] ho\,Cos\left[K\frac{hA}{L}\frac{\sqrt{K\frac{hA^{2}}{L} - 4q\alpha ho}}{2q} \right] t \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (33)$$

The rate fluid flow in the study area become imperative to monitor the influences on the phosphorus deposition in soil and water environment , the flow rate of fluid are determined by structural deposition of the formation as its is deposited in the formation. The rate of fluid flow in the soil are structured by the deposition of the soil, such condition were base this dimension in the system, the study focuses' on the permeability and porosity in the formation, the rate of fluid flow were expressed mathematically to ensure that the rate of fluid movement are monitored, because the deposition of substrate phosphorus are base on the rate fluid flow within the organic and lateritic soil.

4. Conclusion

The flow of fluid in vertical under the influences of phosphorus has been mathematically developed, the model generate parameters that bare influential to the deposition of phosphorus and fluid flow in the study area. The derived solution pass through different approach of mathematical expression to generate a better solution that will definitely monitor the deposition of phosphorus and rate fluid flow in a vertical column, the system express various dimension that fluid are influenced in soil and water environments the formation express it various variations that may influences movement of fluid flow in vertical column, such condition reflect the migration of substrate deposition phosphorus in the strata. The developments of mathematical equation were to ensure that the expressed parameters are monitor to determine their deposition at every stratum within monitored formation. The developed governing equation will definitely descretize the rate of formation in influences on the deposition of microelements and express the behaviour of the substrate under the influences of fluid flow in vertical column.

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