World Journal of Environmental and Chemical Engineering
Vol. 1, No. 1, June 2015, pp. 1 - 9
Available online at http://www.wjece.com/

Research article

PREDICTING E. COLI TRANSPORT INFLUENCED BY PRESSURE FLOW IN SAND GRAVEL FORMATION IN COASTAL AREA OF PORT HARCOURT

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

Abstract

The impact from pressured flow were considered in sand gravel formation, the deposition from this influences were monitored in coastal area of port Harcourt, the study were to monitor pressure flow impact on the migration process of E.coli in unconfined bed, several expert has developed some model on various stratum of the formation, but they have not consider the system in sequences on homogeneous deposited formation in coastal locations. The behaviour of the transport were observed to have been influences by pressured flow of solute fluid in the study area, base on these factors the development of the system were able to generate the governing equation that produced model at various conditions, the parameters in the system were integrated base their various relation in homogeneous setting through the geological history in the study location. Experts will definitely applied these model to monitor the migration state of E.coli on area pressured flow impact in deltaic environment are predominant.

Keywords: E.coli transport, pressure flow, and sand grave

---

1. Introduction

Correct acquaintance of the transport and fate of bacteria in subsurface surroundings is needed for many practical Scenarios. An understanding of bacteria movement, for example, is applied to evaluate the risk that pathogenic microorganisms pose to water resources (Ginn et al., 2002 Gargiulo,et al 2008), to develop efficient water treatment methods (Tufenkji et al., 2002; Ray et al., 2002; Weiss et al., 2005), and to design bioremediation strategies for hazardous waste sites (Mishra et al., 2001; Vidali, 2001). Mobile colloids, such as bacteria, can also facilitate the transport of a wide variety of inorganic and organic contaminants that can absorb onto these high surface area

World Journal of Environmental and Chemical Engineering
Vol. 1, No. 1, June 2015, pp. 1 - 9
Available online at http://www.wjece.com/

particles (Kim et al., 2003; Šimůnek et al., 2006). Considerable research has been devoted to the fate and transport of microbes and other colloids in porous media in Schijven and Hassanizadeh, 2000; Harvey and Harms, 2002 For example, Wan and Tokunaga (2002) demonstrated in bubble column experiments that only positively charged particles attached to the negatively charged air–water interface. Column transport experiments conducted under carefully controlled conditions of solid and/or aqueous phase chemistry have indicated that enhanced retention of colloids in unsaturated systems is unlikely to be due to attachment at the air–water interface (Chuet al., 2001; Chen and Flury, 2005). Models of attachment to the solid–water and air–water interfaces have traditionally assumed a constant first-order deposition term, which predicts an exponential spatial distribution of retained colloids with distance (e.g., Yao et al., 1971; Logan et al., 1995; Tufenkji and Elimelech, 2004a). Under unfavorable attachment conditions (when repulsive electrostatic interactions exist between the colloids and a porous medium), however, retained colloids in saturated porous media frequently do not exhibit an exponential distribution with depth, and the deposition rate has been found to be depth dependent (Albinger et al., 1994; Baygents et al., 1998; Simoni et al., 1998; Bolster et al., 2000; DeFlaun et al., 1997; Zhang et al., 2001; Redman et al., 2001; Bradford et al., 2002, 2006b; Li et al., 2004; Bradford and Bettahar, 2005; Tong et al., 2005a,b). A variety of chemical and physical explanations have been proposed in the literature to account for these observations (Tan et al., 1994; Liu et al., 1995; Johnson and Elimelech, 1995; Kretzschmar et al., 1997; Cushing and Lawler, 1998; Bolster et al., 1999; Redman et al., 2001, 2004; Bradford et al., 2002, 2003, 2004, 2005; Tufenkji et al. 2003, 2004; Li et al. 2004, 2005; Hahn et al., 2004; Tufenkji and Elimelech, 2004b, 2005a,b; Bradford and Bettahar, 2005 Gargiulo,et al 2008).

2. Theoretical Background

The development of the principal equation is to monitor the flow pressure impact on the migration of E.coli in sand gravel formation. The developed governing equation were established from the system through these variables that were noted to generate the most impact on the transport system of the microbes, the developed governing equation will be derived to monitor the migration in several condition from the pressured induced flow that increase the migration of the contaminant in the study area. Pressure flow from sand gravel are the focus of these study, this is precisely on the influences from pressured flow, the deposition of high pressured flow in the study area implies these deposited strata may have developed high degree of porosity in homogeneous formation, the rate of flow in sand gravel will always develop high influences from these direction of fluid in through the intercedes of the homogeneous setting, this generate higher pressure migrating E.coli transport to phreatic bed. pressure flow are base on the rate of homogeneous deposition whereby the degree of permeability will always relate with void ratio of sand gravel, these relationship expressed the behaviour of E.coli in homogeneous formation under pressured induces condition. The pressure flow impact on E.coli transport in such homogeneous strata express higher velocity in sand gravel formation thus direction of flow in these phase of the transport system. The migration of the microbes will always follow the direction of flow base on the rate of velocity within time interval from one formation to another, these expression are connected to the migration with respect to time in homogenous structural setting of the

World Journal of Environmental and Chemical Engineering
Vol. 1, No. 1, June 2015, pp. 1 - 9
Available online at http://www.wjece.com/

formation. Aquifer thickness in migration of E.coli under the influences of pressure flow impact can be noted to be higher in unconfined bed, the rate of pressured induced impact are influenced by higher degree of porosity between the unconfined bed determined by the thickness of aquifer in the study area. Pressure induced flow impact on E.coli transport will be derived to be monitored at various phase of the transport system.

3. Governing equation

$$\bar{V}\frac{\partial c^2}{\partial t^2} = \bar{K}h_{(x)}\frac{\partial c}{\partial Z} - \frac{Q}{n_e}\frac{\partial c}{\partial Z} \quad \ldots\ldots\ldots\ldots \quad (1)$$

The developed governing equation is base on the fundamental parameter that was observed to pressure the transport of E.coli in study location. The developed expression were generated to these sources to monitor the rate of flow pressured in sand gravel, there rate flow may influenced by their deposit velocity under the impact of void percentage between intercedes of the formation. Such expression establish various impact of the parameters connecting together to generate pressure flow rate concentration in E.coli migration in the study location.

Nomenclature

C	=	E.coli concentration
$h_{(x)}$	=	Aquifer thickness
$\bar{K}$	=	Homogenous permeability
Q	=	Rate of flow
n_e	=	Porosity
T	=	Time
Z	=	Variation Depth

Substituting $C = TZ$

$$\bar{V}ZT^{11} = \bar{K}h_{(x)}Z^1T - \frac{Q}{n_e}Z^1T$$

Dividing by T,Z, we have

$$\bar{V}\frac{T^{11}}{T} = \bar{K}h_{(x)}\frac{Z^1}{Z} - \frac{Q}{n_e}\frac{Z^1}{Z} \quad \ldots\ldots\ldots\ldots \quad (2)$$

$$\bar{V}T^{11} = \bar{K}h_{(x)}Z^1 - \frac{Q}{n_e}Z^1 = \beta^2 \quad \ldots\ldots\ldots\ldots \quad (3)$$

$$\bar{V}\frac{T^1}{T} = \beta^2 \quad \ldots\ldots\ldots\ldots \quad (4)$$

$$\overline{K}h_{(x)}\frac{Z^1}{Z} = \beta^2 \qquad \text{.......................................} \qquad (5)$$

$$-\frac{Q}{n_e}\frac{Z^1}{Z} = \beta^2 \qquad \text{.......................................} \qquad (6)$$

This implies that equation (5) and (6) can be expressed as:

$$\left[\overline{K}h_{(x)} - \frac{Q}{n_e}\right]\frac{Z^1}{Z} = \beta^2 \qquad \text{.......................................} \qquad (7)$$

$$\overline{V}\frac{T^{11}}{T}\frac{dc}{dt} = \beta^2 \qquad \text{.......................................} \qquad (8)$$

$$\overline{V}\frac{d^2}{dt^2} = \beta^2 \qquad \text{.......................................} \qquad (9)$$

$$\overline{K}h_{(x)}\frac{dc}{dz} = \beta^2 \qquad \text{.......................................} \qquad (10)$$

$$\frac{Q}{n_e}\frac{dc}{dz} = \beta^2 \qquad \text{.......................................} \qquad (11)$$

$$d^2 z = \left[\frac{\beta^2}{\overline{\overline{V}}}\right] = dz \qquad \text{.......................................} \qquad (12)$$

$$\int d^2 - \int \frac{\beta^2}{\overline{\overline{V}}} dz \qquad \text{.......................................} \qquad (13)$$

$$dz = \frac{\beta^2}{\overline{\overline{V}}} z + C_1 \qquad \text{.......................................} \qquad (14)$$

$$\int dz = \int \frac{\beta^2}{\overline{\overline{V}}} z\, dz + C_1 \int dz \qquad \text{.......................................} \qquad (15)$$

$$z = \frac{\beta^2}{\overline{\overline{V}}}\frac{z^2}{2} + C_1 + C_2 \qquad \text{.......................................} \qquad (16)$$

$$z = \frac{\beta^2}{\overline{\overline{V}}}\frac{z^2}{2} C_1 z + C_2 \qquad \text{.......................................} \qquad (17)$$

$z = 0 \quad z = 0$

$$z = \frac{\beta^2}{2\overline{V}} z^2 + C_1 z + C_2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

The developed model on pressured induces flow impact on E.coli were monitor considering these phases of the developed model, the thickness of aquifers on these condition were considered at theses phase of the derived solution, the developed model monitored the parameters that may played serious roles on the deposition of the contamination under the influences of distance in aquifer thickness in the system. Subject to this condition on the transport phase, it has become more explicit that the derived model at these phase are consider base on the depth interval in the migration process of the contaminant.

Auxiliary Equation becomes:

$$\Rightarrow \frac{\beta^2}{2\overline{V}} z^2 + C_z + C_2 = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

Applying quadratic expression we have

$$M = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

$$M_{1,2} \quad \frac{-C_1 \sqrt{C^2 - 4\frac{(\beta^2)}{4\overline{V}} C_2}}{\frac{\beta^2}{\overline{V}}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

$$M_1 = \frac{-C_1 + \sqrt{C^2 - 2C_2 \frac{\beta^2}{2\overline{V}}}}{\frac{\beta^2}{\overline{V}}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

$$M_2 = \frac{-C_1 - \sqrt{C_1^2 - 2C_2 \frac{\beta^2}{\overline{V}}}}{\frac{\beta^2}{\overline{V}}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

Assuming this discriminate is a complex root, therefore, equation (22) and (23) can be expressed as:

$$C = [T, Z] = D_1 \, Cos \, M_1 t + D_2 \, Sin \, M_2 z \qquad \ldots\ldots\ldots\ldots \quad (24)$$

But if $t = \frac{d}{v}$

$$C = [T, Z] = D_1 \, Cos \, M_1 \frac{d}{V} + D_2 \, Sin \, M_2 \frac{d}{V} \qquad \ldots\ldots\ldots\ldots \quad (25)$$

The expression here is the final derived models for the study, the rate of pressure flow between the unconfined beds are base on the permeability relationship with void ratio in the formation. These expressions were thorough capture in the derived solution base on various relationships in the study area. The derived solution express these model in various dimensions in other to monitor their various impacts which has been found to pressure the flow in unconfined bed contaminated by E.coli depositions. The behaviour of the system was base on this expressed parameter at various phase of the developed model.

4. Conclusion

Pressures flow found to increase the concentration of E.coli transport were precisely studied in this research work, the behaviour of the contaminants were observed in the study location through samples of ground water including the lithology subjected to thorough experiments, these condition were monitor to find out other impact that may pressured the transport system, the parameters considered generated the system producing the governing equation, the derived solution considered the rate of pressure and its sources from the deposited formation to generate derived model under various phase of the transport system. Pressure flows are noted to developed lots of influences from velocity of flow, these were integrated on the derived solution expressing various concepts that may have developed the increase of concentration in sand gravel formation.

References

Albinger, O., B.K. Biesemeyer, R.G. Arnold, and B.E. Logan. 1994. Eff ect of bacterial heterogeneity on adhesion to uniform collectors by monoclonal populations. FEMS Microbiol. Lett. 124:321–326.

Baygents, J.C., J.R. Glynn, Jr., O. Albinger, B.K. Biesemeyer, K.L. Ogden, and R.G. Arnold. 1998. Variation of surface charge density in monoclonal bacterial populations: Implications for transport through porous media. Environ. Sci. Technol. 32:1596–1603.

Bolster, C.H., A.L. Mills, G.M. Hornberger, and J.S. Herman. 1999. Spatial distribution of deposited bacteria following miscible displacement experiments in intact cores. Water Resour. Res. 35:1797–1807.

Bolster, C.H., A.L. Mills, G. Hornberger, and J. Herman. 2000. Effect of intrapopulation variability on the long-distance transport of bacteria. Ground Water 38:370–375.

Bradford, S.A., and M. Bettahar. 2005. Straining, attachment, and detachment of Cryptosporidium oocysts in saturated porous media. J. Environ. Qual. 34:469–478.

Bradford, S.A., and M. Bettahar. 2006. Concentration dependent colloid transport in saturated porous media. J. Contam. Hydrol. 82:99–117.

Bradford, S.A., M. Bettahar, J. Simunek, and M.Th . van Genuchten. 2004. Straining and attachment of colloids in physically heterogeneous porous media. Vadose Zone J. 3:384–394.

Bradford, S.A., and F.J. Leij. 1997. Estimating interfacial areas for multi-fluid soil systems. J. Contam. Hydrol. 27:83–105.

Bradford, S.A., J. Simunek, M. Bettahar, Y.F. Tadassa, M.Th . van Genuchten, and S.R. Yates. 2005. Straining of colloids at textural interfaces. Water Resour. Res. 41:W10404, doi:10.1029/2004WR003675.

Bradford, S.A., J. Simunek, M. Bettahar, M.Th . van Genuchten, and S.R. Yates. 2003. Modeling colloid attachment, straining and exclusion in saturated porous media. Environ. Sci. Technol. 37:2242–2250.

Bradford, S.A., J. Šimůnek, M. Bettahar, M.Th . van Genuchten, and S.R. Yates. 2006a. Significance of straining in colloid deposition: Evidence and implications. Water Resour. Res. 42:W12S15, doi:10.1029/2005WR004791.

Bradford, S.A., J. Simunek, and S.L. Walker. 2006b. Transport and straining of *E. coli* O157:H7 in saturated porous media. Water Resour. Res. 42:W12S12, doi:10.1029/2005WR4805.

Bradford, S.A., Y.F. Tadassa, and Y. Pachepsky. 2006c. Transport of *Giardia* and manure suspensions in saturated porous media. J. Environ. Qual. 35:749–757.

Bradford, S.A., and S. Torkzaban. 2008. Colloid transport and retention in unsaturated porous media: A review of interface, collector, and pore scaleprocesses and models. Vadose Zone J. (in press).

Chen, G., and M. Flury. 2005. Retention of mineral colloids in unsaturated porous media as related to their surface properties. Coll. Surf. Physicochem. Eng. Aspects 256:207–216.

Chu, Y., Y. Jin, M. Flury, and M.V. Yates. 2001. Mechanisms of virus removal during transport in unsaturated porous media. Water Resour. Res. 37:253–263.

Cushing, R.S., and D.F. Lawler. 1998. Depth fi ltration: Fundamental investigation through three-dimensional trajectory analysis. Environ. Sci. Technol. 32:3793–3801.

DeFlaun, M.F., C.J. Murray, M. Holben, T. Scheibe, A. Mills, T. Ginn, T. Griffi n, E. Majer, and J.L. Wilson. 1997. Preliminary observations on bacterial transport in a coastal plain aquifer. FEMS Microbiol. Rev. 20:473–487.
Ginn, T.R., B.D. Wood, K.E. Nelson, T.D. Scheibe, E.M. Murphy, and T.P. Clement. 2002. Processes in microbial transport in the natural subsurface. Adv. Water Resour. 25:1017–1042.

Harvey, J.W., and H. Harms. 2002. Tracers in groundwater: Use of microorganisms and microspheres. p. 3194–3202. *In* G. Britton (ed.) Encyclopedia of environmental microbiology. John Wiley & Sons, New York.

Hahn, M.W., D. Abadzic, and C.R. O'Melia. 2004. Aquasols: On the role of secondary minima. Environ. Sci. Technol. 38:5915–5924.

Johnson, P.R., and M. Elimelech. 1995. Dynamics of colloid deposition in porous media: Blocking based on random sequential adsorption. Langmuir 11:801–812.

Kim, S.B., M.Y. Corapcioglu, and D.J. Kim. 2003. Eff ect of dissolved organic matter and bacteria on contaminant transport in riverbank fi ltration. J. Contam. Hydrol. 66:1–23.

Kretzschmar, R., K. Barmettler, D. Grolimun, Y.D. Yan, M. Borkovec, and H. Sticher. 1997. Experimental determination of colloid deposition rates and collision effi ciencies in natural porous media. Water Resour. Res. 33:1129–1137.

Li, X., T.D. Scheibe, and W.P. Johnson. 2004. Apparent decreases in colloid deposition rate coefficient with distance of transport under unfavorable deposition conditions: A general phenomenon. Environ. Sci. Technol. 38:5616–5625.

Li, X., P. Zhang, C.L. Lin, and W.P. Johnson. 2005. Role of hydrodynamic drag on microsphere deposition and re-entrainment in porous media under unfavorable conditions. Environ. Sci. Technol. 39:4012–4020.

Liu, D., P.R. Johnson, and M. Elimelech. 1995. Colloid deposition dynamics in fl ow-through porous media: Role of electrolyte concentration. Environ. Sci. Technol. 29:2963–2973.

Logan, B.E., D.G. Jewett, R.G. Arnold, E.J. Bouwer, and C.R. O'Melia. 1995. Clarification of clean-bed filtration models. J. Environ. Eng. 121:869–873.

Mishra, S., J. Jeevan, C.K. Ramesh, and L. Banwari. 2001. In situ bioremediation potential of an oily sludge-degrading bacterial consortium. Curr. Microbiol. 43:328–335.

Redman, J.A., S.B. Grant, T.M. Olson, and M.K. Estes. 2001. Pathogen filtration, heterogeneity, and the potable reuse of wastewater. Environ. Sci. Technol. 35:1798–1805.

Ray, C., T.W. Soong, Y.Q. Lian, and G.S. Roadcap. 2002. Effect of fl ood-induced chemical load on filtrate quality at bank fi ltration sites. J. Hydrol. 266:235–258.

Redman, J.A., S.L. Walker, and M. Elimelech. 2004. Bacterial adhesion and transport in porous media: Role of the secondary energy minimum. Environ. Sci. Technol. 38:1777–1785.

Schijven, J.F., and J. Simunek. 2002. Kinetic modeling of virus transport at the field scale. J. Contam. Hydrol. 55:113–135.

Simoni, S.F., H. Harms, T.N.P. Bosma, and A.J.B. Zehnder. 1998. Population heterogeneity affects transport of bacteria through sand columns at low fl ow rates. Environ. Sci. Technol. 32:2100–2105.

Šimůnek, J., C. He, J.L. Pang, and S.A. Bradford. 2006. Colloid-facilitated transport in variably saturated porous media: Numerical model and experimental verification. Vadose Zone J. 5:1035–1047.

Tan, Y., J.T. Cannon, P. Baveye, and M. Alexander. 1994. Transport of bacteria in aquifer sand: Experiments and model simulations. Water Resour. Res. 30:3243–3252.

Tong, M., T.A. Camesano, and W.P. Johnson. 2005a. Spatial variation in deposition rate coefficients of an adhesion-defi cient bacterial strain in quartz sand. Environ. Sci. Technol. 39:3679–3687.

Tong, M., X. Li, C.N. Brow, and W.P. Johnson. 2005b. Detachment-influenced transport of an adhension-deficient bacterial strain within water-reactive porous media. Environ. Sci. Technol. 39:2500–2508.

Tufenkji, N., J.N. Ryan, and M. Elimelech. 2002. Th e promise of bank filtration. Environ. Sci. Technol. 36:422a–428a.

Tufenkji, N., and M. Elimelech. 2004a. Correlation equation for predicting single-collector efficiency in physiochemical filtration in saturated porous media. Environ. Sci. Technol. 38:529–536.

Tufenkji, N., and M. Elimelech. 2004b. Deviation from the classical colloid filtration theory in the presence of repulsive DLVO interactions. Langmuir 20:10818–10828.

Vidali, M. 2001. Bioremediation: An overview. Pure Appl. Chem.73:1163–1172.

Wan, J.M., and T.K. Tokunaga. 2002. Partitioning of clay colloids at air–water interfaces. J. Colloid Interface Sci. 247:54–61.

Weiss, W.J., E.J. Bouwer, R. Aboytes, M.W. LeChevallier, C.R. O'Melia, B.T.Le, and K.J. Schwab. 2005. River fi ltration for control of microorganisms results from fi eld monitoring. Water Res. 39:1990–2001.

Yao, K.M., M.T. Habibian, and C.R. O'Melia. 1971. Water and waste water fi ltration: Concepts and applications. Environ. Sci. Technol. 5:1105–1112.

Zhang, P., W.P. Johnson, T.D. Scheibe, K. Choi, F.C. Dobbs, and B.J. Mailloux. 2001. Extended tailing of bacteria following breakthrough at the Narrow Channel Focus Area, Oyster, Virginia. Water Resour. Res. 37:2687–2698

G. Gargiulo, S. A. Bradford,* J. Simunek, P. Ustohal, H. Vereecken, and E. Klumpp 2008; Bacteria Transport and Depositio under Unsaturated Flow Condition: The Role of Water Content and Bacteria Surface Hydrophobicity Soil Science Society of America 677 S. Segoe Rd. Madison, WI 53711 USA.