Research Journal of Water, Soil and Air Pollution
Vol. 1, No. 1, November 2013, PP: 10 - 17
Available online at http://scitecpub.com/Journals.php

Research article

MODELING NITROGEN DISPERSION INFLUENCED BY PERMABILITY AND POROSITY ON E.COLI GROWTH RATE IN SILTY AND FINE SAND FORMATION IN KHANNA, RIVERS STATE OF NIGERIA

Eluozo, S. N

[1]Subaka Nigeria Limited, Port Harcourt, Rivers State of Nigeria
Director & Principal Consultant, Civil & Environmental Engineering,
Research & Development
E-mail: Soloeluozo2013@hotmail.com
E-mail: solomoneluozo2000@yahoo.com

Abstract

Modeling nitrogen deposition influenced by porosity and permeability in silty and fine sand formation were examined in the study area, the deposition of nitrogen and E.coli in silty and fine sand formation has confirmed the deposition of the two parameters in aquitard and penetrating unconfined bed in the study area. These conditions implies that the deposition has experienced lots of accumulation especially the lateritic soil, but the deposition o degree porosity and permeability in silty and fine sand formation at high degree has influences the migration through porosity and permeability that has develop high deposition of nitrogen and E.coli in silty and fine sand formation. Base on the these factor mathematical model were found imperative to develop model that will express E.coli deposition and nitrogen and E.coli growth rate in silty and fine sand formation that deposit aquitard and penetrating unconfined bed, the model will be a base line for experts to structure the prevent guild line of soil pollution in the study area.

Keywords: modeling nitrogen, permeability and porosity, E.coli growth rate, and fine sand formation.

1. Introduction

Groundwater may be polluted, when wastewater penetrated into the soil and recharges groundwater via leaking sewerage systems, seepage from manure, wastewater or sewage sludge dispersing by farmers on fields, waste from creatures feedlots, waste from healthcare amenities, seepage from waste discarding sites and landfills, or artificial renew of treated waste water. If the distance from source of contamination to spot of abstraction is small, there is a real possibility of abstracting pathogens. To forecast the presence of pathogens in water, usually a separate group of microbes is used. The ordinary expressive period for this group of organisms is fecal indicator organisms (Medema et al., 2003), from which *Escherichia coli* (or *E. coli*) and thermotolerant coliform microorganisms are two significant members. *E. coli* is widely favorite and used as an index of fecal pollution (World Health Organization, 2003), because its discovery is comparatively simple, fast and consistent, and the organism is regularly calculated in water samples throughout the world. The same applies to thermotolerant ('fecal') coliforms. These coliforms are a less consistent index of fecal pollution than *E. coli*, although under most conditions their concentrations are directly related to *E. coli* concentrations (World Health Organization, 2003). Viruses may be considered more critical to groundwater quality than *E. coli*. Because of their smaller size, stability, and negative charge, they may be transported even further through the ground, and because of their infectiousness they represent a major threat to public health Ground water resources are heavily used for domestic drinking water supplies in the United States and most of the world. Nationally, 40% of the U.S. domestic water supply originates from ground water. Furthermore, over 40 million people use ground water to supply their drinking water via domestic wells (Alley 1999). Of public water systems in the U.S., 92% rely primarily on ground water for supply (Craun 2002). Worldwide, ground water represents a large majority of the drinking water supply in many nations, including Denmark, Portugal, Italy, Switzerland, Belgium, and the Netherlands, all of which derive more than 2/3 of their drinking water from ground water (Pedley and Howard 1997). Aquifers have, until the last few decades, been generally considered protected from potential sources of microbial or chemical contamination typically found in surface waters. Due to increasing population densities, agriculture, development and industrialization, and increased withdrawals from aquifers, however, the quality of ground water is increasingly a concern. Numerous instances of ground water contamination and waterborne illness due to ingestion of ground water have been documented. Microbial contamination of ground water has been responsible for many disease outbreaks. In the U.S., at least 356 outbreaks of disease caused by contaminated ground water were documented between 1971 and 1994, representing 58% of all waterborne illness outbreaks (Craun and Calderon 1997). Data for a more recent period (1991 - 1998) indicated that 74 outbreaks of waterborne illness occurred due to public water systems that used ground water, representing 68% of the waterborne disease outbreaks during that period (Craun 2002). This is likely an underestimation of overall incidence of illness due to frequent non detection of outbreaks and a lack of reporting on sporadic and self-resolving illnesses. However, serious consequences can be the result, as estimated annual waterborne disease deaths in the U.S. were reported in one review to be 900 - 1800 (Macler and Merkle 2000). In developing countries in Asia, South America and Africa for an estimated 1,300 million urban dwellers the main source of drinking water is groundwater (Foster, 2000). This groundwater may be contaminated by infiltrated wastewater, because very often a sewer system is not present and households dispose of their solid and liquid waste on-site. For instance, in Africa around 80% of the population in the largest cities (in Asia: around 55%) have on-site sanitation, such as septic tanks, pour-flush, VIP latrines or simple pits (World Health Organization, 2000-2003). To predict the presence of pathogens in water, a separate group of microorganisms is usually used, generally known as fecal indicator organisms (Pedley et al., 2005). Many microorganisms have been suggested as microbial indicators of fecal pollution (like enterococci, coliphages and sulphite reducing clostridial spores; Medema et al., 2003), but two of the most important indicators used worldwide are *Escherichia coli* and thermotolerant coliform bacteria (for microbiological definitions of these indicators, both are widely used, because their detection is relatively simple, fast, and reliable. *E. coli* is the preferred indicator of fecal contamination, as it is the only member of the thermotolerant coliform group that is invariably found in feces of warm-blooded animals and it outnumbers the other thermotolerant coliforms in both human and animal excreta (Medema et al., 2003). Thermotolerant coliforms are a less reliable index of fecal contamination than *E. coli*, although under most circumstances their concentrations are directly related to *E. coli* concentrations (Payment et al., 2003). Viruses may be considered as the most critical or limiting microorganism. Because of their small size, their mostly negative surface charge, and their high persistence in the environment, they may travel long distances in the subsurface. In addition, they can be highly infectious (Schijven, 2001). In the study by Karim et al. (2004a), water from 20 groundwater wells from 11 US states was monitored monthly for one year for the presence of culturable viruses, nucleic acid of enteric viruses Some of the reviews concentrate on the movement of bacteria and viruses in aquifers in a qualitative way, without attempting to predict their migration (e.g. Romero, 1970; Lewis et al., 1980; Hagedorn et al., 1981; Crane and Moore, 1984; Bitton and Harvey, 1992; Stevik et al., 2004). Others mainly focus on first-order die-off rates, thereby neglecting the transport component including attachment and detachment processes (e.g. Reddy et al., 1981; Barcina et al., 1997). Murphy and Ginn (2000) mainly summarize the mathematical descriptions of the various physico-chemical and biological processes involved in the transport of bacteria and viruses, without indicating the relative importance of these processes and their occurrence in the natural environment. Merkli (1975) and Althaus et al. (1982) have presented a comprehensive bacteria transport model based on the colloid filtration theory (Herzig et al., 1970; Yao et al., 1971), including the effects of dispersion, diffusion, sedimentation, and filtration.

2. Theoretical background

The deposition of E.coli in Khana has been found to be influenced by high degree of porosity and permeability in the study location, the depositions of nitrogen in that formation were found to develop high degree of E.coli in Khana location of Rivers State. The deposition of micronutrient nitrogen has been the paramount increasing of E.coli population in the study area, the deposition in silty and fine sand formation implies that the contaminants are deposited within the aquitard and penetrating unconfined bed in the study area, high degree of porosity and permeability deposition influences the migration and increase of the microbes within the silty and fine sand formation, these condition implies that other soil formation deposited above these two formation samples may have experiences accumulation before the variation on the increase of these influential formations characteristics developed predomination in silty and fine sand formation of the soil. The expressed model consider several conditions stated in the system before the established derived governing equation were modified.

3. Governing Equation

$$K\phi \frac{\partial c^2}{\partial t^2} = QV \frac{\partial}{\partial z} + D\frac{\partial c}{\partial z} - K\frac{\partial c}{\partial z} + K_o \frac{\partial c}{\partial t} + K_n \frac{\partial c}{\partial z} \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$\frac{\partial^2 c}{\partial t^2} = S^2 C_{(t)} - SC - SC_{(o)} \qquad \ldots\ldots\ldots\ldots \qquad (2)$$

$$\frac{\partial c}{\partial z} = SC_{(z)} - C_{(z)} \qquad \ldots\ldots\ldots\ldots \qquad (3)$$

$$\frac{\partial c}{\partial z} = SC_{(z)} - C_{(z)} \qquad \ldots\ldots\ldots\ldots \qquad (4)$$

$$\frac{\partial c}{\partial z} = SC_{(z)} - C_{(z)} \qquad \ldots\ldots\ldots\ldots \qquad (5)$$

$$\frac{\partial cs}{\partial t} = SC_{(t)} - C_{(t)} \qquad \ldots\ldots\ldots\ldots \qquad (6)$$

$$\frac{\partial c}{\partial t} = SC_{(t)} - C_{(t)} \qquad \ldots\ldots\ldots\ldots \qquad (7)$$

$$K\phi\left[S^2 C_{(t)} - SC_{(t)} - SC_{(0)}\right] + VQ\left[SC_{(z)} - C_{(0)}\right]D\left[SC_{(z)} - C_{(0)}\right] - K_o$$

$$\left[SC_{(t)} - C_{(0)}\right] + K_n\left[\left(SC_{(z)} - C_{(0)}\right)\right] \qquad \ldots\ldots\ldots\ldots \qquad (8)$$

$$K\phi\left[S^2 C_{(t)} - C_{(t)} - C_{(0)}\right] + VQ\left[SC_{(z)}{}^2 - 2SC_{(z)}\left(C_{(0)}\right)^2\right]K + 2SC_{(z)}C_{(o)} \qquad \ldots\ldots \qquad (9)$$

$$C_{(o)} + K_n\left(SC_{(z)}\right)^2 - 2Sc_{(z)}\left(C_{(o)} - C_{(o)}\right)^2$$

Equating (9) into time t, we have

$$K\phi\left[S^2 C_{(t)} - SC_{(t)} - C_{(0)}\right] + VQ\left[SC_{(z)}{}^2 - 2SC_{(z)}\left(C_{(0)}\right)^2\right] - \qquad \ldots\ldots\ldots\ldots \qquad (10)$$

$$-K\left(SC_{(z)}\right)^2 - 2SC_{(z)}C_{(0)} + \left(C_{(0)}\right)^2 + K_o\left(SC_{(z)}\right)^2 - 2SC_{(z)}C_{(0)} + \left(C_{(0)}\right)^2 \qquad \ldots\ldots\ldots\ldots \qquad (11)$$

Rearranging (11) yield $a^2 - 2ap + p(a-b)^2$

$$\left(1+K_o\right)\left(SC_{(t)}\right)^2 - \left(1+K_o\right)2S_{(t)}C_{(0)} + \left(1+K_o C_{(0)}\right)^2 \qquad \ldots\ldots\ldots\ldots \qquad (12)$$

$$\left[\left(SC_{(t)}\right)^2 - 2SC_{(t)}C_{(0)} + \left(C_{(0)}\right)^2\right]\left(1+K_o\right) \qquad \ldots\ldots\ldots\ldots \qquad (13)$$

$$\left(SC_{(t)}\right)^2 - 2SC_{(t)}C_{(0)} + \left(C_{(0)}\right)^2 \frac{K_n}{(K_o)} \qquad \ldots\ldots\ldots\ldots \qquad (14)$$

$$\left[SC_{(z)} - C_{(0)}\right]^2 - \frac{K_n}{(1+K_o)} \qquad \ldots\ldots\ldots\ldots \qquad (15)$$

$$SC_{(x)} - C_{(0)} = \sqrt{\frac{K_n}{C(1+K_o)}} = \pm 1\sqrt{\frac{K_n}{C(1+K_o)}} \qquad \ldots\ldots\ldots\ldots \qquad (16)$$

$$SC_{(x)} = C_{(0)} = \sqrt{\frac{K_n}{C(1+K_o)}} \qquad \text{...........} \quad (17)$$

$$C_{(z)} = C_{(0)} + 1\sqrt{\frac{K_n}{C(1+K_o)}} \qquad \text{...........} \quad (18)$$

F(x) when $x > 0 \;\; C_{(o)} = C_0$

$$C_{(z)} = \frac{C_0}{C} + 1\sqrt{\frac{\frac{K_n}{C(1+K_o)}}{C}} \qquad \text{...........} \quad (19)$$

Hence, in any direction of *x*, we have

$$C_{(z)} = \ell^{\frac{C_0}{C}} \left[ACos \sqrt{\frac{\frac{K_n}{C(1+K_o)}}{C}} + BSin \sqrt{\frac{\frac{K_n}{C(1+K_o)}}{C}} \right] z \qquad \text{...........} \quad (20)$$

$$\Rightarrow \; C_{(z)} = \ell^{C_0 t} \left[ACos \sqrt{\frac{K_n}{C(1+K_o)}}\, t + BSin \sqrt{\frac{K_n}{C(1+K_o)}} \right] z \qquad \text{...........} \quad (21)$$

Again, we consider (10), so that we have

$$K\phi\left[S^2 C_{(t)} - SC_{(t)} - C_{(0)}\right] + VQ\left[SC_{(z)}{}^2 - 2SC_{(z)}\left(C_{(0)}\right)^2\right]$$

$$K\phi\left[S^2 C_{(t)} - SC_{(t)} - C_{(0)}\right] = -VQ\left[SC_{(t)} - \left(C_{(0)}\right)^2\right] \qquad \text{...........} \quad (22)$$

$$\frac{S^2 C_{(t)} - SC_{(t)} - C_{(0)}}{\left(SC_{(t)} - C_{(0)}\right)^2} = \frac{VQ}{K\phi} \qquad \text{...........} \quad (23)$$

$$SC_{(t)} - C_{(0)} \neq 0 \qquad \text{...........} \quad (24)$$

Considering the LHS of the numerator of (23) gives

$$C_{(t)} = \frac{S \pm \sqrt{S^2 + 4S^2 C_{(o)}}}{2S^2} \qquad \text{...........} \quad (25)$$

$$C_{(t)} = \frac{1}{2S} \frac{\pm\sqrt{1+4C_{(o)}}}{2S} \qquad \text{...........} \quad (26)$$

When $t > 0 \;\; C_{(o)} = C_0$

$$C_{(t)} = A\ell^{\frac{1}{2}\left(1+\sqrt{1+C_o}\right)t} + B\ell^{\frac{1}{2}\left(1-\sqrt{1+C_o}\right)t} \qquad \text{...........} \quad (27)$$

Since the denominator of the LHS of (23) has equal Roots

$$C_{(t)} = -\frac{VQ}{K\phi}(C+Dt)\ell^{(t\ -C_o)t} \qquad \ldots \quad (28)$$

Combining equation (27) and (28), we have

$$C_{(t)} = -\frac{VQ}{K\phi}(C+Dt)\ell^{(1\,-\,C_o)t} + A\ell^{\frac{1}{2}\left(1+\sqrt{1+\,C_o}\right)t} + B\ell^{\frac{1}{2}\left(1-\sqrt{1+-\,C_o}\right)t} \qquad \ldots\ldots\ldots\ldots \quad (29)$$

If $t = \frac{x}{V}$

$$C_{(z,v)} = A\ell^{\frac{1}{2}\left(1+\sqrt{1+\,C_o}\right)\frac{z}{v}} + B\ell^{\frac{1}{2}\left(1-\sqrt{1+\,C_o}\right)\frac{z}{v}} - \frac{VQ}{K\phi}(C+Dt)\,\ell^{(1\,-\,C_o)\frac{z}{v}} \qquad \ldots \quad (30)$$

The expressed derived model has been developed to monitor nitrogen dispersion influenced by permeability and porosity on E.coli growth rate in silty and fine sand formation, permeability and porosity were found to be the most major influences in the stratification in the study location, this was confirmed from previous laboratory analysis that examined permeability and porosity to establish the highest degree of the two parameters in the study area, the result from the analysis were applied in the formulation of the system, the influences from these two parameters increase the deposition of E.coli and its microelements in silty and fine sand formation , these two sample formation are found to deposit aquitard and penetrating unconfined bed in the study area, such condition made the expressed model imperative because it will determine the rate influenced of porosity and permeability on E.coli deposition and migration in silty and fine sand formation.

4. Conclusion

Model studies of analytical theoretical values have been evaluated, this is to establish to be compared in simulating the model, and this will be compared with experimental results. their relations in model prediction of nitrogen deposition influencing E.coli transport in homogeneous silty and fine sand formation, the study is in Khana location in Rivers state , there are lots of deltaic formation influence, this condition were assessed thus make imperative to establish two different predictive values to monitor the deposition of nitrogen on E.coli transport in the study location. Formation of this type that has lots of shallow aquifers deposition including high degree of porosity are observed to develop lots of challenges in predicting pollution deposition in the study area, this factors find it necessary to establish two different model and compare both results to determine their relationship. The result of both p models has been confirmed from the comparative studies carried out, both models values establish a relationship were both results were on exponential phase as presented from the figures , these are reflected on the experimental laboratory analysis that were original compared with the analytical values, before the comparative models, it implies that both parameter compared can predict perfectly the deposition of nitrogen reflected on E.coli transport in homogeneous coarse and fine sand. The model establish base on the comparative analysis can be applied to predict the deposition of ammonia on E.coli migration in the study area.

References

[1] Althaus, H., K.D. Jung, G. Matthess and A. Pekdeger, 1982. Lebensdauer von Bacterien und Viren in Grundwasserleitern. Umweltbundesamt, Materialien 1/82. Schmidt-Verlag, Berlin

[2] Alley, W. M., Reilly, T. E. and Franke, O. L. (1999). Sustainability of Ground-Water Resources, U.S. Geological Survey Circular 1186. Denver, U.S. Geological Survey.

[3] Craun, G. F., Nwachuku, N., Calderon, R. L. and Craun, M. F. (2002). "Outbreaks in drinking-water systems, 1991-1998." Journal of Environmental Health **65**(1): 16-23.

[4] Macler, B. A. and Merkle, J. C. (2000). "Current knowledge on groundwater microbial pathogens and their control." Hydrogeology Journal **8**(1): 29-40.

[5] Medema, G. J., Bahar, M. and Schets, F. M. (1997). "Survival of Cryptosporidium parvum, Escherichia coli, faecal enterococci and Clostridium perfringens in river water: Influence of temperature and autochthonous microorganisms." Water Sci Technol **35**(11-12): 249-2

[6] Medema, G. J., Bahar, M. and Schets, F. M. (1997). Survival of Cryptosporidium parvum, Escherichia coli, faecal enterococci and Clostridium perfringens in river water: Influence of temperature and autochthonous microorganisms." Water Sci Technol **35**(11-12): 249-2

[7] Pedley, S. and Howard, G. (1997). "The public health implications of microbiological contamination of groundwater." Q J Eng Geol **30**: 179-188.

[8] Foster, S.S.D., 2000. Groundwater resources at the turn of the millennium: taking stock and lookingforward. In: *Groundwater: past achievements and future challenges, Sillo et al. (eds.),*Balkema, Rotterdam, The Netherlands, ISBN 90 5809 159 7.

[9] World Health Organization, 2000-2003. Global Water Supply and Sanitation Assessment 2000 Report. http://www.who.int/docstore/water_sanitation_health/globassessment

[10] Payment, P., M. Waite and A. Dufour, 2003. Introducing parameters for the assessment of drinking water quality. In: *Assessing microbial safety of drinking water: improving approaches and methods, Dufour et al. (eds.).* World Health Organization, 2003. ISBN 92 4 154630.

[11] Schijven, J.F., G. Medema, A.J. Vogelaar, and S.M. Hassanizadeh, 2000. Removal of microorganisms by deep well injection. J. Contam. Hydrol., Vol. 44, p. 301-327.

[12] Romero, J.C., 1970. The movement of bacteria and viruses through porous media. Ground Water (8), p. 37-48

[13] Karim, M.R., F.D. Manshadi, M.M. Karpiscak and C.P. Gerba, 2004b. The persistence and removal of enteric pathogens in constructed wetlands. Wat. Res. (38), p. 1831-1837.

[14] Lewis, W.J., Foster, S.S.D. and Drasar, B.S., 1980. The risk of groundwater pollution by on-site sanitation in developing countries. IRCWD Report No. 01/82. International Reference Centre fr Waste Disposal (IRCWD), Duebendorf, Switzerland

[15] Hagedorn, C., E.L. McCoy and T.M. Rahe, 1981. The potential for ground water contamination from septic effluents. J. Environ. Qual. (10), p. 1-8.

[16] Crane, S.R. and J. Moore, 1984. Bacterial pollution of groundwater: a review. Water, Air, Soil Pollution (22), p. 67-83.

[17] Bitton, G. and R.W. Harvey, 1992. Transport of pathogens through soils and aquifers. In: Environmental Microbiology, edited by R. Mitchell, ISBN 0-471-50647-8, p. 103-124.

[18] Stevik, T.K., K. Aa, G. Ausland and J.F. Hanssen, 2004. Retention and removal of pathogenic bacteria in wastewater percolating through porous media: a review. Wat. Res. (38), p. 1355-1367

[19] Reddy, K.R., R. Khaleel and M.R. Overcash, 1981. Behavior and transport of microbial athogens and indicator organisms in soils treated with organic wastes. J. Environ. Qual. (10), p. 255- 266.

[20] Merkli, B., 1975. Untersuchungen ueber Mechanismen und Kinetik der Elimination von Bakterien und Viren im Grundwasser. Diss. ETH Zurich 5420.

[21] Barcina, I., P. Lebaron and J. Vives-Rego, 1997. Survival of allochthonous bacteria in aquatic systems: a biological approach. FEMS Microbiol. Ecol. (23), p. 1-9.

[22] Murphy, E.M., J. M. Zachara, and S. C. Smith, 1990. Influence of mineral-bound humic substances on the sorption of hydrophobic organic compounds. Environ. Sci. Technol., Vol. 24, p. 1507-1516

[23] Herzig, J.P., D.M. Leclerc, and P. Le Golf, 1970. Flow of suspensions through porous media – Application to deep infiltration. In: Flow Through Porous Media, Am. Chem. Soc., Washington, D.C., pp. 129-157

[24] Yao, K-M, M.T. Habibian and C.R. O'Melia, 1971. Water and wastewater filtration: Concepts and Applications. Environmental Science and Technology Vol. 5, Number 11, p. 1105-1112.

[25] David E. John 2003 Transport and survival of water quality indicator microorganisms in the ground water environment of Florida: Implications for aquifer storage and waste disposal PhD Dissertation University of south Florida pp1-5.

[26] Jan Willem Anton Foppen 2007 Transport of *Escherichia coli* in saturated porous media Taylor & Francis Group plc, London, UK pp- 1-6