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Research article

MODELING THE RATE OF E.COLI TRANSPORT THROUGH FLUID PRESSURE IN HOMOGENOUS FINE SAND FORMATION IN COASTAL AREA PORT HARCOURT, NIGER DELTA OF NIGERIA

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Abstract

Modeling the rate of E.coli transport influenced by fluid pressure has been mathematically expressed. E.coli transports are determined through the deposition of soil stratification under the influence of geological setting in the study location. Permeability and porosity were found to develop several leaching of E.coli concentration at different formations. Consequently, ground water aquifers contaminating within a short period of time, constant regeneration of these contaminants has developed high rate of E.coli concentration to a very large extend**,** these are through regeneration of the pollution, thus dispersion and diffusion playing some roles despite influence from formation characteristics. Environmental conditions were found to influence the system as high rain intensities generated high degrees of soil saturation, increasing aquiferous water level. The model were derived through formulated governing equations, expressed equations were developed considering the variables that influence the system, this concept were to express the variation of fluid flow based on soil stratification. This condition developed several variation of velocity of E coli transport, under the influence of porosity and permeability function in the system. Variations of fluid pressure were expressed with respect to period of E.coli transport thus increasing ground water contaminants, these include distance travelled to ground water aquifers and other existence influences in the formations. The study is imperative because the rate of fast migration of other substance that inhibit the microbes are through the influence of regeneration of the solute, the influence from formation characteristics such as porosity and permeability were found to play major roles in fast migration of these microbes. The degrees of these two parameters determine the rate of variations of E.coli concentration in soil and water environment, since variation in fluid flow established the status of ground water conditions in the study area.

Keywords: modeling the e.coli transport through fluid pressure and homogenous formation

1. Introduction

Escherichia coli, originally called "*Bacterium coli* commune," was first isolated from the feces of a child in 1885 by Theodor Escherichia and nowadays is the best-studied bacterium. *Escherichia coli* are common Inhabitant of the

gastrointestinal tract of humans and animals. There are *E. coli* strains that are harmless commensal of the intestinal tract and others that are major pathogens of humans and animals. The pathogenic *E. coli* is divided into those strains causing disease inside the intestinal tract and others capable of infection at extra intestinal sites (Kaper et al., 2004). *Escherichia coli* is easily cultured in the clinical laboratory, but the identification of the different pathogenic genotypes requires virulence gene detection methods. *Escherichia coli* can be found secondarily in soil and water as the result of fecal contamination. Classically, its detection has been used as an indicator of poor water and/or food quality. From biochemical, physiological and genetic perspectives, *E. coli* is one of the best understood and characterized living organisms, with laboratory studies on model strains such as *E. coli* K-12 taking place over the past sixty years.

Besides *E. coli*, there are other species within the genus, *E. adecarboxylata*, *E. blattae*, *E. fergusonii*, *E. hermanii* and *E. vulneris*. Little is known about the distribution, biology or interrelatedness of these species. Evolutionary studies based on either DNA sequence analysis or multilocus enzyme electrophoresis has identified clonal phylogenetic groupings of *E. coli*. Phylogenetic studies have principally used the *E. coli* reference (ECOR) strain collection as a common reference for current evolutionary comparisons (Ochman & Selander, 1984). Six phylogenetic groups are generally recognized among the ECOR strains: A, B1, B2, C, D and E, (Selander et al., 1987).Infections due to pathogenic *E. coli* may be limited to colonization of a mucosal surface or can disseminate throughout the body and have been implicated in urinary tract infection, sepsis/meningitis and gastrointestinal infections (Nataro & Kaper, 1998). Due to the ease of access of pathogens ingested with food, the human gastro-intestinal tract is susceptible to diarrhoeagenic *E. coli* infections. Several *E. coli* pathotype have been implicated with diarrheal illness, a major public health problem worldwide, with over two million deaths occurring each year (Kosek et al., 2003).

Genome sequencing of three different *E. coli* strains (laboratory K-12 strain MG1655, enterohemorrhaghic O157:H7 strain EDL933, and an uropathogenic isolate, CFT073) reveals an unambiguous conservation of nearly 40% of the core gene sequences among the three isolates (Welch et al., 2002). The synteny of the genes around the circular chromosomes is nearly intact and representative of the classic *E. coli* K-12 gene map (Berlyn, 1998). *Escherichia coli* are common inhabitants of the small intestine and large intestine of mammals. They are often the most abundant facultative anaerobes in this environment. The human colon maintains a microbial density approaching 1012 organisms per gram of feces, representing a perfectly balanced ecosystem. The commensal microbiota consists of more than 400 species and lives in perfect harmony with the human intestine (Hooper & Gordon, 2001). They can occasionally be isolated in association with the intestinal tract of no mammalian animals and insects. The presence of *E. coli* in the environment is usually considered to reflect fecal contamination and not the ability to replicate freely outside the intestine. There is evidence however to suggest that *E. coli* may freely replicate in tropical fresh water (Bermudez & Hazen, 1988).

But, unfortunately, there is “trouble in paradise”. Much research is being done on water quality and beach monitoring. As this research progresses, problems with the current system of monitoring are brought to light. (Nevers and Whitman, In Press) Researchers today have discovered that *E. coli* may not always be an effective indicator of water quality. While it is true that *E. coli* is found in the intestines of warm blooded animals, scientists

have recently revealed that E. coli can also persist and perhaps thrive in many other natural environments! (Whitman and Nevers, 2003) Take soil for example. Research conducted at the USGS Lake Michigan Ecological Research Station (USGS LMERS) has shown that temperate forest soils in the Indiana Dunes harbor *E. coli* throughout the entire year (winter included)! The sediments and soil in the watershed of Dunes Creek (a Lake Michigan tributary) contain *E. coli*, and the persistently high *E. coli* counts in Dunes Creek itself may be due to rainfall and stream flow eroding the sediment-borne bacteria into the water. In these cases there was no significant human fecal input, yet the *E. coli* was there. (Byappanahalli, et al., 2003)

What about sand? *E. coli* is found in beach sand as well! Bacteria harbored in sand may even persist longer than in water because the bacteria adhere to sediment particles, unlike bacteria that are free in the water. (Whitman and Nevers, 2003) When various advisories keep swimmers out of the water, many people will remain on the beach. According to Research has shown that *E. coli* counts were higher in the near shore sand and submerged sand than in the beach water. Additionally, the *E. coli* counts were typically several orders of magnitude higher in the sand than in the water. The geometric mean of *E. coli* counted in the foreshore sand in a study on 63rd street beach in Chicago was 4,000 CFU's/ 100 ml of water, as compared to only 43 CFU's /100 ml water in the water. (Whitman and Nevers, 2003)*E. coli* is even in the algae! *E. coli* comes from many natural sources, and can reproduce in *Cladophora*, a kind of green algae found in the open waters of Lake Michigan. *Cladophora* often amasses along the Lake Michigan beaches, and harbors high densities of *E. coli* relative to beach sand. (Whitman, et al., 2003)*E. coli* seems to be virtually everywhere! It's in the water bodies that are uncontaminated by humans. It's in the soil. It's in the algae. One recent study even found *E. coli* in the fluid of bog dwelling pitcher plants! (Shively, et al., 2004) Not only can *E. coli* exist in these parts of the environment, but recent studies indicate that in some of these areas they can actually reproduce as well! In one research project in the Indiana Dunes, hot water was used to treat the forest soil, killing off all but extremely small numbers of *E. coli.* After the heat treatment, not only did the bacteria multiply, but they persisted in the test plot for more than one year afterward! (Byappanahalli, et al., 2002).

E. coli are commonly motile in liquid by means of peritrichous flagella. *E. coli* are commonly fimbriated. The type 1 pili are the most common and are expressed in a phase switch on or off manner that leads to piliated and nonpiliated states (Eisenstein, 1987). One of the traits commonly encoded on the larger genetic islands of the different pathotype of *E. coli* are additional pili (chaperone-usher and type IV pili families and non-pili adhesions (Schreiber & Donnenberg, 2002). Among *E. coli* isolates, there is considerable variation and many combinations of somatic (O and K) and flagellar (H) antigens. Among pathogenic strains, there are few patterns of these antigens and few phylogenetic groupings. For *E. coli*, there are over 150 antigenically unique O-antigens (Whitfield & Valvano, 1993). K type capsular material occurs in two or four forms on the basis of physical, biochemical and genetic criteria (Whitfield Roberts, 1999).

2. Theoretical Background

The transport of E.coli is a serious issue to environmental health, E.coli are generated from several source of deposition of soil and water, high deposition of E.coli are generated from biological waste from man made

activities, this type of microorganism are found in human faces and animal blood, indiscriminate dumping of biological waste including our soak away pit obtain the highest percentage of microbial generation, there are other sources of this contaminants, but the mention sources are the commonest source of this microbial deposition in the study area. Microbes are living organism, there behaviour and availability in water keep them living, their deposition in soil is either they station in a particular soil formation or they migrate to another soil environment that will be faviourable for them, but most instance they are found reducing through death rate, another behaviour of E.coli is that when they deposit in soil, they increase in microbial population through substrate deposition, thus migrate from one region to the other in soil and water environment. Microelements are one of the sources of E.coli energy in there transport process, the deposition of microelements implies that the concentration of E.coli will increase to high percentage in soil and water environment, but fast transportation of this microbes are influenced by several factors in soil and water environment, geological setting and it variation determine the rate migration in the strata, the formation characteristics varies at various degrees, the geological formation are deltaic in nature, there lots of influence in deltaic environments, another factors are environmental influence from climatic conditions, these are major factors that influence fast migration of the microbes to ground water aquifers.

3. Governing Equation

$$Sop\frac{\partial^2 p}{\partial t^2} + \left[\varepsilon w\frac{\partial p}{\partial t}\right] w\frac{\partial p}{\partial t} - \frac{\partial p}{\partial x_1}\left[\frac{K_1 p}{\mu}\right]\left[\frac{\partial p}{\partial x_j} + pg\frac{\partial p}{\partial x_i}\right] = QP_z \quad \ldots\ldots\ldots\ldots \quad (1)$$

Taking Laplace transformation of (1)

$$\frac{\partial^2 p}{\partial t^2} = S^2 P_{(t)} - SP - P_{(0)} \quad \ldots\ldots\ldots\ldots \quad (2)$$

$$\frac{\partial p}{\partial t} = SP_{(t)} - P_{(t)} \quad \ldots\ldots\ldots\ldots \quad (3)$$

$$\frac{\partial p}{\partial t} = SP_{(t)} - P_{(t)} \quad \ldots\ldots\ldots\ldots \quad (4)$$

$$\frac{\partial p}{\partial x} = SP_{(x)} - P_{(x)} \quad \ldots\ldots\ldots\ldots \quad (5)$$

$$\frac{\partial p}{\partial x} = SP_{(x)} - P_{(x)} \quad \ldots\ldots\ldots\ldots \quad (6)$$

$$P = P_{(0)} \quad \ldots\ldots\ldots\ldots \quad (7)$$

The rate of E. coli present in soil and water environment are through constant regeneration from man made activities, the deposition of these microbes from man made activities are through various condition as it is expressed in various direction mathematically from equation 2 to 7, the variable that represent this various condition of microbial behaviour are mathematically transform into Laplace, this is to express there functions according to various function in the system, the variables will express there relation to each other at different phase, under the influence of soil stratification. This has deposited high degree of porosity at various soil formation thus leaching of the microbes to ground water aquifers, subject to this transformation, expression were generated through the substitution stated in the equations bellow.

Submitting equation (2), (3), (4), (5), (6) and (7) into equation (1), yields

$$Sop\left[S^2P_{(t)} - SP_{(t)} - P_{(0)}\right] + \varepsilon w\left[SP_{(t)} - P_{(0)}\right]w\left[SP_{(t)} - P_{(0)}\right] - \left[SP_{(x)} - P_{(0)}\right]\frac{Kp}{\mu}$$

$$\left[\left[SP_{(t)} - P_{(0)} + Pg\,(SP_{(t)} - P_{(0)})\right]\right] = QPz \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

$$-2SP_{(x)}P_{(0)} - (P_{(0)})^2 + Pg\left(SP_{(t)}\right)^2 - 2SP_{(x)}P_{(0)} - (P_{(0)}{}^2) = QP_z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

The expression from equation 8 were to correlate the variables in the system with the transformation from equation 2 to 7 as express above, the relation with these variables streamline the state E.coli deposition through fluid pressure in several direction under the influence of formation characteristics in the system.

Equating (9) with respect to time, *t*, we have

$$Sop\left[S^2P_{(0)} - SP_{(t)} - P_{(0)}\right] + \varepsilon w^w\left[(SP_{(t)})^2 - 2SP_{(0)} + P_{(0)})^2\right] = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

Equating (9), with respect to Time direction of flow gives

$$-\frac{Kp}{\mu}\left(Sp_{(x)}\right)^2 - 2SP_{(t)}P_{(0)} + \left(P_{(0)}\right)^2 + Pg\left(Sp_{(x)}\right)^2 - 2SP_{(t)}P_{(0)} + \left(P_{(0)}\right)^2 = QP_Z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

Rearranging (11), yields

$$a^2 - 2ap + P(a-p)^2$$

$$(1+Pg)\left(Sp_{(x)}\right)^2 - (1+Pg)2SP_{(t)}P_{(0)} + (1+Pg)\left(P_{(0)}\right)^2 = \frac{QP_Z\mu}{K,P} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

$$\left[\left(Sp_{(x)}\right)^2 - 2SP_{(t)}P_{(0)} + \left(P_{(0)}\right)^2\right](1+Pg) = -\frac{QP_Z\mu}{K,P} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

$$\left(Sp_{(x)}\right)^2 - 2Sp_{(x)}P_{(0)} + \left(P_{(0)}\right)^2 = -\frac{QP_Z\mu}{K,P(1+Pg)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

$$\left[Sp_{(x)} - P_{(0)}\right]^2 = -\frac{QP_Z\mu}{K,P(1+Pg)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

$$\left[Sp_{(x)} - P_{(0)}\right]^2 Sp_{(x)} - P_{(0)} = -\sqrt{\frac{-QP_Z\mu}{K,P(1+Pg)}} = \pm i\sqrt{\frac{QP_Z\mu}{K,P(1+Pg)}} \quad \ldots\ldots\ldots\ldots\ldots \quad (16)$$

$$P_{(x)} = P_{(0)} \pm i\sqrt{\frac{QP_Z\mu}{K,P(1+Pg)}} \quad \ldots\ldots\ldots\ldots\ldots \quad (17)$$

To monitor the rate of E.coli deposition in the system, the introduce expression is to discretize different variables functions express in the equation, this expression is to monitor the concentration at various condition, these are under the influence of formations variations through the geological setting in the study area. The variables in the system express influential roles include monitoring the direction of flow that influences the migration of E.coli through the stratification of the formation. It developed fast migration of E.coli to ground water aquifers. Such expression implies that the microbes will definitely experience high concentration under the influence of these variables in the system, because it influence the migration of E.coli from one region to another under the influence of formation characteristics, the rate of variation through the influence of such deposition of are observed from the rate of porosity that deposit in the study area. Equations from 10 to 17 through the influential variables expressed, these generated the functions that influence the variation of E.coli concentration in the system.

$$Sp_{(x)} = P_{(0)} \pm i\sqrt{\frac{QP_Z\mu}{K,P(1+Pg)}} \quad \ldots\ldots\ldots\ldots\ldots \quad (18)$$

When $x > 0,\ P_{(0)} = P_0$

$$P_{(x)} = \frac{P_0}{S} \pm i\sqrt{\frac{QP_Z\mu}{K,P(1+Pg)}} \quad \ldots\ldots\ldots\ldots\ldots \quad (19)$$

Hence in any direction *x*, we have

$$P_{(x)} = \ell^{P_0/S}\left[A\,Cos\sqrt{\frac{\frac{QP_Z\mu}{K,P(1+Pg)}}{S}} + B\,Sin\sqrt{\frac{\frac{QP_Z\mu}{K,P(1+Pg)}}{S}}\right]x \quad \ldots\ldots\ldots\ldots\ldots (20)$$

$$\Rightarrow \quad P_{(x)} = \ell^{P_{0t}}\left[A\,Cos\sqrt{\frac{\frac{QP_Z\mu}{K,P(1+Pg)}t}{S}} + B\,Sin\sqrt{\frac{\frac{QP_Z\mu}{K,P(1+Pg)}t}{S}}\right]x \quad \ldots\ldots\ldots \quad (21)$$

Again, we consider (10) so that we have

$$Sop\left[S^2P_{(t)} - SP_{(t)} - P_{(0)}\right] + \varepsilon w^w\left[(SP_{(t)})^2 - 2SP_{(t)}\,P_{(0)} + P_{(0)})^2\right] = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

$$Sop\left[S^2P_{(t)} - SP_{(t)} - P_{(0)}\right] = -\varepsilon w^w\,(SP_{(t)} - P_{(0)})^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

$$\frac{S^2P_{(t)} - SP_{(t)} - P_{(0)}}{\left(SP_{(t)} - P_{(0)}\right)^2} = \frac{-\varepsilon w^w}{Sop} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

$$SP_{(t)} - P_{(0)} \neq 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (25)$$

Considering the left hand side of the number of (23) gives

$$P_{(t)} = \frac{S \pm \sqrt{S^2 + 4S^2P_{(o)}}}{2S^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (26)$$

$$P_{(t)} = \frac{\frac{1}{2S} \pm \sqrt{1 + 4P_{(o)}}}{2S} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (27)$$

When $t > 0,\ P_{(o)} = P_o$

The expressions of Boundary conditions were incorporated on the application of quadratic expression; this is to monitor the variation of E.coli deposition at different formations, velocity of transport with respect to change in distance were thoroughly expressed, formation characteristics express the influence to ground water aquifers through these stated parameters, . These expressions are in line with the boundary values that were applied in equation 25. Subject to this relation, the expressions that determine the variation of velocity of E.coli transport, in this phase are based on soil stratification under the influence of geological setting in the study location. .

So that $P_{(t)} = \frac{1}{2S} \pm \frac{\sqrt{1 + P_o}}{2S}$

Hence $P_{(t)} = A\ell^{\frac{1}{2}\left(1+\sqrt{1+P_o}\right)t} + B\ell^{\frac{1}{2}\left(1-\sqrt{1+P_o}\right)t}$ …….. (28)

Since the Denominator of the left hand side of (23) has equal roots;

$$P_{(t)} = \frac{-\varepsilon w^w}{Sop}\left(C + Dt\right)\ell^{(t-P_o)t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

Combining equation (28), we have

$$P_{(t)} = \frac{-\varepsilon w^w}{Sop}\left(C + Dt\right)\ell^{(t-P_o)t} + A\ell^{\frac{1}{2}\left(1+\sqrt{1+P_o}\right)t} + B\ell^{\frac{1}{2}\left(1-\sqrt{1+P_o}\right)t} \quad \ldots\ldots\ldots\ldots \quad (30)$$

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

$$\boxed{P_{(x,v)} = A\ell^{\frac{1}{2}\left(1+\sqrt{1+P_o}\right)t} + B\ell^{\frac{1}{2}\left(1-\sqrt{1+P_o}\right)\frac{x}{v}} - \frac{\varepsilon w^w}{Sop}\left(C + Dt\right)\ell^{(1-P_o)\frac{x}{v}}} \quad \ldots\ldots\ldots\ldots \quad (31)$$

The expression in (31) shows final model equation that will monitor the rate of E.coli migration at different stratum in the study location, fast migration of the microbes' will definitely determine the rate of its concentration to groundwater aquifers. E.coli depositions in soil are as a result of constant regeneration from constant dumping of wastes in the study area. The derived mathematical equations were generated through the governing equation; the expressed equation will monitor the concentration of E.coli at various formations to groundwater aquifers. Variation influences of microbial transport from various strata are through geological setting. This has been a serious concern to environmental experts. This is because lots of ground water are not thoroughly examine, due to the rate of contamination from E.coli deposition at various formations in soil and water environment, the rate of these microbial deposition in the study area has generated several illness from these type of pollution sources, E.coli concentration in soil and water environment should be observed, this is to examine the migration of such pollutant through fluid pressure to ground water aquifers. The study of E.coli deposition is imperative because knowing the rate of concentration in the environment especially were waste are deposit, will made the experts ensure that risk assessment are carried out. Thus Prevention in ground water design through factor of safety application will be applied. To monitor this type of contaminant, mathematical model that will prevent any sources of pollution were developed. The negligence from this direction has also resulted to a lot of water-related diseases, such investigation were ignored in the study location. Variation of E.coli in soil and water environment were found to influences the leaching of these contaminants through high percentage of formation micropoles, this condition play a major roles in microbial transport to aquiferous zones, therefore the rate of velocity of E.coli transport through variation of structural deposition of soil formation are the fundamental solute concentration in ground water aquifers. modeling the rate of E.coli transport will definitely determine the migration of the microbes, some experience inhibition depending on the rate of inhibitors deposition in the formations, such influence are from degrees of permeability and porosity of the soil, direction of fluid flow through soil strata influence the direction of microbial transport and deposition in soil. The developed model will assist engineers to monitor the rate of E.coli deposition in the study location, this has resulted to several victims of illness in the study area, and groundwaters are the major source of water for human utilization. Thousands of people in the study area got their water from public water supply and private boreholes. Subject to this relation, the rate of water related diseases cannot be overemphasized due to this ugly scourge.

4. Conclusion

velocity of transport are determine by numerous factors, the velocity of transport are through soil geological setting, the stratification formation deposition are influence by the degree of porosity and permeability of the strata, the study area are predominant with deltaic stratification, these condition implies that the formation has lots of environmental influence through climatic condition, including the activities of man. E.coli deposition are influence from soil stratification to ground water aquifers, the study area experienced regeneration of this microbial concentration, thus this increased the concentration to a large extend the rates of pollution migrating to ground water aquifer are the subject of concern in the study area. And this are influenced through velocity from flow path,

the result from Fast migration of microbial concentrations is through the degree of porosity of the formation, this were examined through the developed mathematical model, more so, formation characteristics through the micropoles at high degree of depositions were also confirmed to influenced variation of E.coli velocity of transport, this determine the rate of fluid flow variation in strata to ground water aquifers, the expression in the study location is through hydrological studies, information from hydrological studies were confirmed to express several formation characteristics that influences the deposition of E.coli concentration at various formations, this generated microbial increase influential in transport system, the formation deposit several fluid pressures as presented in shallow aquifers, the deltaic nature in the study location deposit homogenous soil formation, this condition implies that the fluid dynamics in soil are found to be predominantly as expressed in the deltaic environment. To monitor the rate of E.coli deposition in the study area, mathematical model were found to be a suitable concepts that determine the rate of E.coli concentration in the study area. The model were derived through the governing equation developed to solve the problem, the governing equation were derived considering several conditions that influence the variation of fluid flow in deltaic environment, the derived mathematical model will monitor the rate E.coli concentration at different formation in the study area.

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