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Research article

MODELING ON INVERSE TRANSPORT OF SALMONELLA IN SILTY SAND COLUMN IN COASTAL AREA OF BAKANA, RIVERS STATE OF NIGERIA

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Abstract

Salmonella transports in coastal environment are found to be under the influence of formation characteristics, the concepts are observed the migration process of the microbe' under the influences of the stated variables in the system.. Salmonella known to have lots of diversity of behaviour, these condition were considered when the system were developed, major variables in the system are concentration of the microbes under the influence of formation characteristics and coefficient of mass transfer, these parameters determine the rate of salmonella deposition at every formation, degree of porosity also has lots of variation, therefore salmonella behaviour are influenced by the rate of soil porosity, the system developed an equation considering this parameters as major role in fast migration of the microbes under the influence of this variables, other parameters were also found to have played other role in the transport system, the developed mathematical equation method applied separation of variables, the derived solution express parameters at various state with their functions at different phase of the migration process in the system. it is denoted with mathematical tools, the model are express base on the behaviour of the salmonella at different phase on the transport process in coastal environment.

Keywords: modeling, inverse transport, salmonella and coastal area of bakana

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1. Introduction

Individual excreta have customarily been used for crop fertilisation in many countries. In Japan

The recycling of urine and faeces was introduced in the 12th Century and in China human and animal excreta have been composted for thousands of years (Esrey *et al.* 1998 Caroline, 2001). In Swedish cities, organised collection and transportation of latrine products to farmers started in the 18th Century (Tingsten 1911, Caroline, 2001). As the population grew, quantities increased and treatment alternatives to facilitate the handling of excreta were developed. Pudrett, a mixture of latrine products and peat provided a fertiliser without smell that could be transported long distances (Tingsten 1911). Decreasing the risk for transmission of disease was another implication for further refinement of the latrine products (Wetterberg and Axelsson 1995). The latrine products were also mixed with lime to produce limed ammonium nitrate and ammonium sulphate (Tingsten 1911). Another product used as fertiliser was urat, consisting only of urine mixed with peat litter (Bachér *et al.* 1944 Caroline, 2001). During the 19th Century urine was stored and used as a detergent for washing clothes in Denmark (Hansen 1928, in Drangert 1998). In Sweden urine has been used to smear wounds and dry skin and to some extent to drink as therapy (Frode-Kristensen 1966). Other historic uses of urine include tanning of hides and production of gunpowder (Stenström 1996 Caroline, 2001). Public water supplies were introduced for several reasons in Sweden, among them to improve sanitary conditions and fight epidemics of cholera (Isgård 1998). Access to water was a necessity for the use of water closets (WC), which during the middle of the 19th Century were introduced in Europe (Cronström 1986). In Sweden the first "official" WC was installed in 1883 but the introduction was quite slow due to the prohibition against using water for flushing purposes (Cronström 1986). There was also an intense debate ongoing at that time in which the health authorities and physicians argued for WCs whereas those against feared clogging and pollution of waters (Lundgren 1994). The implementation of WCs would also end the recycling and utilization of plant nutrients from urine and faeces in agriculture. Representatives for the farmers therefore argued against the implementation of WCs (Lundgren 1994). The effect of plant nutrients and the need for recycling of manure and latrine products was known according to Liebig's mineral theory (Mårald 2000 Caroline, 2001). The latrine contents produced in the cities were considered "a mine of wealth" (Goddard 1996). At the same time the role of hygienic practices was more widely realized in Europe. Bacteria were recognised as spreading disease and connected to uncleanliness and immorality, not considered to belong in a modern society (Mårald 2000). The use of latrine products in agriculture was questioned. In England Chadwick tried to combine hygiene and reuse of nutrients. One solution he advocated was the application of wastewater on agricultural fields, removing microorganisms through soil filtration (Chadwick 1842, in Mårald 2000 Caroline, 2001).

2. Theoretical Background

Years past in Niger delta region environment, development of ground water has been known to have a lost it's of qualities due to lack of appropriate design and construction. these implies that there is several substandard practice in development of drinking water standard, nevertheless, in specific areas, natural ground water chemistry does not comply with the standard specifications for human utilization, the contamination source are generated from biological waste including nitrates fluorides iron manganese, but the focus of this study is centered the variety of microorganism in natural waters in different place at different conditions. Salmonella are microbe specie that are washed into the water from air, it deposit in soil almost every imaginable object. Important numbers of salmonella specie can move through porous media even when the proportion retained is very high. The faeces of animals contain vast numbers of the microbes enter many natural water systems, the size of opening in subsurface material can be unspecified to be variable and are usually not calculated, but porosity and permeability measurement on aquifers sediments indicate that adequate, even in some dense porous rocks. Spaces for bacterial exist in many sediments types. These conditions experienced on bacterial migration in soil and water environment, the developed equation considered the variables in formulating the system. The inverse transport of bacterial are influence on the stated variables, the study area is deltaic environment and the influence from the geologic history are base on the deltaic nature of the soil, these were expressed in the parameters considered in the system, the mathematical expression will be derived to express various condition of bacterial transport to ground water aquifer,

3. Governing Equation

$$\beta\frac{\partial C}{\partial T} = \frac{1}{Pe}\frac{\partial^2 C}{\partial Z^2} - \frac{\partial C}{\partial Z} - w(C-S) \quad \ldots\ldots \quad (1)$$

Nomenclature Dimensionless

C = Concentration of salmonella

β = Fraction of equilibrium sorption site

μ = Deposition coefficient

T = Time

Z = Distance

w = Coefficient of mass transfer

S = salmonella concentration on kinetic adsorption

$$\frac{1}{Pe}\frac{\partial^2 C_1}{\partial Z} = \frac{1}{Pe}\frac{\partial^2 C_1}{\partial Z} \quad \ldots\ldots \quad (2)$$

$$\left.\begin{array}{l} x = 0 \\ t = 0 \\ C_{(o)} = 0 \\ \left.\dfrac{\partial C_1}{\partial Z}\right|_{x=0,\ t=0} = 0 \end{array}\right\} \quad \ldots\ldots \quad (3)$$

$$\beta\frac{\partial C_2}{\partial T} = \frac{\partial C}{\partial Z} - w\,C - S \quad \ldots\ldots \quad (4)$$

$$\left.\begin{array}{l} t = 0 \\ x = 0 \\ C_{(o)} = 0 \end{array}\right\} \quad \ldots\ldots \quad (5)$$

$$\left.\frac{\partial C_2}{\partial T}\right| \quad t = 0, \beta$$

$$\frac{1}{Pe}\frac{\partial^2 C_3}{\partial Z^2} = -\frac{\partial C_3}{\partial Z} - w\,C - S \qquad \text{....................................} \qquad (6)$$

$$\left.\begin{array}{l} x = 0 \\ C_{(o)} = 0 \end{array}\right\} \qquad \text{....................................} \qquad (7)$$

Applying direct integration on (2)

$$\beta\frac{\partial C}{\partial T} = \frac{1}{Pe}C + K_1 \qquad \text{....................................} \qquad (8)$$

Again, integrate equation (8) directly, yields

$$\beta = \frac{1}{Pe}CZ + K_1 z + K_2 \qquad \text{..................................} \qquad (9)$$

Subject to equation (3), we have

$$BCo = K_2 \qquad \text{..................................} \qquad (10)$$

And subjecting equation (8) to (3)

At $\left.\frac{\partial C_1}{\partial Z}\right| \begin{array}{l} = 0 \\ x = 0,\ C_{(o)} = C_o \end{array}$

Yield

Inverse transport or salmonella in silty sand column generate an equation, applying split method techniques to monitor the inverse deposition of salmonella in silty sand column. From equation seven split method techniques showcase different boundary values, this is were parameters are splited to establish their connection and their various function in the system, integrating directly in equation eight, it express a steady subject to the equation by expressing their relationship with respect to concentration and distance, boundary values were stated yielding to equation ten correlating with anther constant under the influence of the boundary values thus concentration and distance

$$0 = \frac{1}{Pe}C_o + K_2$$

$$\Rightarrow \quad K_1 = \frac{1}{Pe}C_o \qquad \text{..................................} \qquad (11)$$

So that, we put (10) and (11) into (9), we have

$$\beta C_1 = \frac{1}{Pe}C_1 z - \frac{1}{Pe}C_o z + \beta C_o \qquad \text{..................................} \qquad (12)$$

$$\beta C_1 = \frac{1}{Pe} C_1 z = \beta C_o - \frac{1}{Pe} C_o z \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

$$\Rightarrow C_1 \left(\beta - \frac{1}{Pez} \right) = C_o \left(\beta - \frac{1}{Pez} \right)$$

$$\Rightarrow C_1 = C_o \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

Hence equation (14), entails that at any given distance, x, we have constant concentration of the contaminant in the system

$$\beta \frac{\partial C_2}{\partial T} = \frac{\partial C_2}{\partial Z} - w \bullet C - S \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

We approach this system by using the Bernoulli's method of separation of variables

$$C_2 - ZT \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

$$\frac{\partial C_2}{\partial T} = ZT^1 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

$$\frac{\partial C_2}{\partial Z} = Z^1 T \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

Put (16) and (17) into (15), so that we have

$$\beta XT^1 = w \bullet C - S \ X^1 T \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

i.e. $\beta \frac{T^1}{T} = w \bullet C - S \frac{X^1}{X} = -\lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$

Hence $\beta \frac{T^1}{T} + \lambda^2 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$

That is,

$$\frac{X^1 + \lambda}{\beta} X = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

$$w \bullet C - S \ X^1 + \lambda^2 T = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

From (21), $X = \frac{ACos\lambda}{\sqrt{\beta}} t + \frac{BSin\lambda}{\sqrt{\beta}} x \quad \ldots\ldots\ldots\ldots \quad (23)$

And (16) gives

$$\boxed{T = C \ell^{\frac{-\lambda^2}{W \bullet C - S} t}} \quad \ldots\ldots\ldots\ldots\ldots \quad (24)$$

Equation 14 developed comparison like equation eight were by variables like coefficient of mass transfer and salmonella concentration including absorption were expressed furthermore, Bernoulli's method were applied, the derived solution equation from 14 to 24 yields a model that expressed the concentration with respect to time, a constant were generated to interacting with coefficient of mass transfer including salmonella coefficient and the concentration of the microbes

By substituting (23) and (24) into (15), we get

$$\boxed{C_2 = \left[A Cos \frac{\lambda}{\sqrt{\beta}}^{t} + B Sin \frac{\lambda}{\sqrt{\beta}}^{x} \right] C \ell^{\frac{-\lambda}{W \bullet C-S} t}} \quad \ldots\ldots\ldots\ldots \quad (25)$$

Subject equation (25) to conditions in (5), so that we have

$$C_o = AC \quad \ldots\ldots\ldots\ldots \quad (26)$$

Therefore, equation (26) become

$$C_2 = C_o \ell^{\frac{-\lambda^2}{w \bullet C-S} t} \quad Cos \frac{\lambda}{\beta} x \quad \ldots\ldots\ldots\ldots \quad (27)$$

Again, at

$$\left. \frac{\partial C_2}{\partial T} \right|_{x = 0,\ B} = 0,\ t = 0$$

Subject to Equation 23 and 24 substituted in to 15 on the derived solution, it produced a model with admiration to time and distance that incorporated the express model of 25 to the situation in 5, this is to streamline initial concentration at equation 26 by high degree of concentration this may be declining with admiration to time and distance under the influences of formation variation through structural deposition of the soil. The pressure in salmonella migration to ground water aquifer further express interaction with other parameters as it is expressed in the system. such experience develop an expression from 27 through coefficient of mass transfer salmonella and concentration were integrated, expressing constant inverse transport of the microbes this showcase the influence of fluctuation through the velocity of transport between the aquiferous zone, boundary values were also integrated to determine their limit between time and distance, it definitely influence concentration with respect to time and distance

Equation (27) becomes

$$\frac{\partial C_2}{\partial t} = \frac{\lambda^2}{\beta} C_o \ell^{\frac{\lambda}{w \bullet C-S}} \quad Sin \frac{\lambda}{\beta} \quad \ldots\ldots\ldots\ldots \quad (28)$$

$C_o \frac{\lambda}{\beta} \neq 0$ Considering NKP

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Which is the substrate utilization for microbial growth (population), so that

$$0 = -C_o \frac{\lambda}{\beta} Sin \frac{\lambda}{\beta}^{B} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

$$\Rightarrow \frac{\lambda}{\beta} = \frac{n\pi}{2}, n = 1,2,3 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

$$\Rightarrow \lambda = \frac{n\pi\sqrt{\beta}}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (31)$$

So that equation (27) becomes

$$C_2 = C_o \ell^{\frac{-n^2\pi^2\beta}{2w \bullet C-S} t \, Cos \frac{n\pi\sqrt{\beta}}{2\sqrt{\beta}} x} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (32)$$

$$\therefore \Rightarrow C_2 = C_o \ell^{\frac{-n^2\pi^2\beta}{2w \bullet C-S} t \, Cos \frac{n\pi\sqrt{\beta}}{2\sqrt{\beta}} x} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (33)$$

The derived solution reflect on when the salmonella experiences transfer process in some stratum, those formation that does not deposit substrate , the microbes may experience slow in transport; due to other influence that will cause degradation in some region of the stratum, the concept absolutely considered these conditions where salmonella experienced degradation, if the microbes become familiarized to the condition of the soil, even if the microbes travel to another soil formation, during the process of transport, it may be reducing its population through death.

Now, we consider equation (6) which is the steady-flow state of the system

$$\frac{1}{Pe} \frac{\partial^2 C_3}{\partial x^2} = -\frac{\partial C_3}{\partial Z} - w \bullet C - S$$

Applying Bernoulli's method, we have

$$C_3 = ZT \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (34)$$

$$\frac{\partial^2 C_3}{\partial Z^2} = Z^{11} T \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (35)$$

$$\frac{\partial C_3}{\partial Z} = Z^1 T \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (36)$$

Put (35) and (36) into (6), so that we have

$$\frac{1}{Pe} Z^{11} T = -w \bullet C - S \, X^1 T \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (37)$$

That is,

$$\frac{1}{Pe} \frac{Z^{11}}{Z} = -w \bullet C - S \frac{Z^1}{Z} = \varphi \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (38)$$

$$\frac{1}{Pe}\frac{Z^{11}}{Z} = \varphi \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (39)$$

$$-w \bullet C - S\frac{Z^{1}}{Z} = \varphi \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (40)$$

That is $Z = A\ell^{\frac{\varphi}{\frac{1}{Pe}}Z}$ ………………………………… (41)

And

$$T = B\ell^{\frac{\varphi}{\frac{1}{Pe}}t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (42)$$

Put (41) and (42) into (34), gives

$$C_3 = A\ell\frac{\varphi}{w \bullet C - S} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (43)$$

$$C_3 = AB\ell^{(x-x)\frac{\varphi}{w \bullet C - S}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (44)$$

original concentration were incorporated as a constant that indicate assumption made, but when there is no substrate utilization for microbial growth this expression from the derived solution 29 were disintegrated to where a model was developed at equation 33, initial value were included bearing in mind the condition that can developed when there is no substrate utilization for microbial growth Moreso, steady state flow of the equation were considered where an assumption was made when the system are on steady state. In this condition the microbes are observed to have deposit a lag phase influenced by inhibitors impermeable layers like clay zone, this expression were disintegrated from equation 34 to 44 were equation 41 and 42 were integrated into 34 that denote an express another behaviour of the salmonella . Assuming the strata porosity of the formation has increase, it implies that coefficient of mass transfer were observed, salmonella concentration and some assumption from it behaviour played a major role including finally concentration with respect to distance. Subject to equation forty four integrated to 7 yields another concentration that expressed initial concentration with respect to of distance This under the influence of porosity and coefficient of mass transfer thus including final concentration. Assumptions were expressed where there is no substrate utilization in that condition the concentration were decrease.

Subject equation (44) to (7), yield

Subject equation (44) to (7), yield

$$C_3 = (0) = C_o \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (45)$$

So that equation (45), becomes

$$C_3 = C_o\,\ell^{(x-x)\frac{\varphi}{w \bullet C - S}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (46)$$

Now assuming that at the steady state flow, there is no NKP for substrate utilization, our concentration here is zero, so that equation (46) become

$$C_3 = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (47)$$

Therefore, solution of the system is of the form

$$C = C_1 + C_2 + C_3 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (48)$$

We now substitute (14), (33) and (47) into (48), so that we have the model

$$C = C_o + C_o\, \ell^{\frac{-n^2\pi^2 \frac{1+fP_bK_d}{\theta}}{2Vd\frac{P_b}{\theta}1+fK_dC-Sk}t} \; Cos\, \frac{n\pi}{2}x \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (49)$$

$$\boxed{C = C_o\, 1+ \ell^{\frac{-n^2\pi^2 \frac{P_b}{\theta}1+fK_dC-Sk}{2Vd\frac{P_b}{\theta}1-fK_dC-Sk}t} \; Cos\, \frac{n\pi}{2}x} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (50)$$

The split expression on the derived solution at equation 6 produced zero, this conclude the expression at equation forty seven, the derived solution in the system expressed is the initial concentration that were splited in different condition denoted mathematically as c_1 to $c_{3,}$ subject to the models by integrating equation 16, 33, 47, into equation 48 generated an expression, integrating all the parameters, it the yield the final model equation that express the collision of salmonella in silty sand column at equation 50 the model develop were to determine the influence that result to salmonella deposition and migration in silty sand column in coastal area of bakana. High rate of porosity through alluvium deposition in the study location express the coefficient of mass transfer fraction of equilibrium sorption will respect to time and distance. Salmonella concentration on kinetic assumption played a major at difference phase of the derived expression this generated a concept to monitor inverse transport of salmonella in silty sand column.

4. Conclusion

The depositions of salmonella are through human and animal actions; these are unsewered settlement, through the onsite sanitation. Including cemeteries waste dump, site and feedlots, such area, microorganism will definitely be predominant in those locations, the situation implies that in soil and water environment, they will accumulated to a very high degree of concentration, in the case of ground water aquifers, it will absolute deposition with high concentration under the influence of constant regeneration in those biological waste in the study locations, the concept is normal in salmonella deposition, and the behaviour of the microbes varies in terms of migration process under the influence of the variation in soil stratification. The influenced from geochemistry and geomorphology of the formation is not left behind, as this also play a major role in some condition on the transport process, in this situation, the inverse transport of microbes occur in the transport process, because in some instant, the deposition of the soil base on the intercedes of the particle grain size, this influences the behaviour of salmonella transport from one formation to the other, therefore inverse transport of salmonella are determined through these influence, the developed mathematical equation considered these experience as variable in the formulation of the system. There inverse transport of salmonella definitely should considered all these parameters in transport process to monitor and development predictive model, the developed model will definitely provide a précised management method for salmonella migration in soil and water environment.

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