International Journal of Waste Management and Technology
Vol. 1, No. 1, April 2013, PP: 23 - 30
Available online www.ijwmt.com

Research article

PREDICTIVE MODEL TO MONITOR THE RATE OF SALMONELLA TRANSPORT THROUGH PLUG FLOW APPLICATION IN LATERATIC AND SILT SAND FORMATION IN COASTAL AREA OF PORT HARCOURT, NIGER DELTA OF NIGERIA

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
E-mail: solomoneluozo2000@yahoo.com

Abstract

Salmonella migration through soil and water environment is a serious threat to groundwater aquifers. The transports of salmonella through the preferential flow are through the micropores of soil formation, warm holes and fracture are another sources of salmonella migration. It is confirmed that microorganisms migrate through soil advection and dispersion, more so, it is subjected to effect of filtration adsorption, desorption, growth, decay, sedimentation and chematoxis, but the focus of the study centered on the influential transport on salmonella through plug flow application, and other formation characteristics in lateritic and silty formation. The study was carried out in coastal area of Port Harcourt, this implies that the formation in such environment will definitely generate coastal aquifer; these variables were considered and found imperative to develop a mathematical model to monitor the migration of salmonella influenced by plug flow in the study area.

Keywords: predictive model of salmonella transport, plug flow application and lateritic and silty sand formation

---

1. Introduction

Environmental and public health problem associated with the spreading of sewage and other biological waste are observed to be increasing in this 21st century. Instance application of sewage are increasing because this disposal process are the methods to remove some of the pollutants from the applied sewage and other biological waste, but are found to possibly constitute a possible aquifer recharge source. Although increase crop and yields by supplying essential nutrients is done by improving soil properties, this concept was monitored by Hugh, et al (1993, Lance, et al 1992, Tim, et al 1998). But the issue is that it does more harm to ground water aquifer, there are the tendency of degrading the quality of surface and groundwater through chemical and microbial contaminants, and accumulation of heavy metals in soil. The spread of agricultural waste may constitutes some source of pathogen to the groundwater, surface and soil. This application of these waste to agriculture has generated regeneration of the salmonella transport through fluid pressure in lateritic and silty formation, the confirmation of this source of pollution make the study imperative to monitor the spread of the pollution source in coastal area of Port Harcourt.

The disaster caused by this source of pollution in Ontario where monitored by Dean and Foran (1990a, 1991b) Fleming, et al (1990) and Palmate et al (1989) that practice the application of liquid manure to agricultural field, this concept result to repaid movement of trace bacterium, nalidixic acid-resistant E.coli through the soil and under drain system leading to contamination of surface receiving water.More so, microbial contamination of water and soil due to land application of liquid manure and other liquid waste is difficult to treat, because once applied, manure becomes a potential non point source of pollution, less susceptible to connection than a point source (Cane et al 1983, Khaheel, et al 1980).

Several microbes like pathogen bacterial and virus that are known to cause diseases has been detected in groundwater, developing nations like Nigeria has experienced several outbreak of some of diseases from groundwater contaminants from pathogenic bacteria and virus, this transport solute to groundwater which include salmonella shigella, E.coli, further outbreak of diseases include hepatitis virus, Norwalk virus, echovirus, poliovirus and coxsackie virus, (Corrapcioglu and Haridas 1984, Caun 1984, Gerber and Keswick, 1981).The application land system where designed on waste disposal by an assumption that the soil will act as a living jutter, with the potential self purification through biological process that can reduce microbial concentration (Tim et al 1988).Meanwhile, there was a significant observation through laboratory process, thus express how microorganisms migrate to a significant distance through soil on both vertical and horizontal direction Chen 1988, Keswick et al 1982, Stewart and Beneau 1981, Viragbaven 1978). Further monitoring of microbial transport was through investigation from surface to 830m, viral migration up to 408m as reported by Gerba et al 1975; Keswick and Gerba 1980).

2.0 Theoretical Background

Predictive model to monitor the rate of salmonella fluid pressure in lateritic and silty sand formation are based on the following dimensions. The ability of microorganisms to migrate through soil and increases the probability of water contamination, the chance of contamination will increase further if microorganisms have the ability to survive for long period of time. (Gerba et al 1975). E.coli survived up to 4 to 5 months in groundwater maintained in darkness under the same condition, Gerba and Keswick (1991) found that a pathogenic strain of E.coli survived for 4 months and a saprophytic strain of E.coli survived 5 months.

Predicting the rate of salmonella through fluid pressure in lateritic and silty sand formation in coastal aquifer are through the basin of the Niger Delta, this consist of massive high porous and gravel which form a multi aquifer system, (Nwankwoala, 2011), including salt water intrusion in unconfined and confined aquifer, but the focus of this study is in unconfined aquifer in coastal area of Port Harcourt. High rate of water pollution from different sources has generated abandonment of borehole projects and abortive wells, in most of the coastal areas; no detailed study to demarcate the interface has been carried out. This situation has resulted to variation in managing degree knowledge and management practice of groundwater aquifers.

To mathematically model and predict the rate of salmonella through fluid pressure in lateritic and silty formation, several conditions that may affect the transport process either fasteror not in migration are considered. This condition is interpreted in the variation of geological formation of the study location and it geological setting under the influence of variation on formation disposition in the study area. The variables were thoroughly expressed as it is itemized to formulate the system, the parameter were integrated to generate the governing equation.The governing equations were developed based on various variables that should influence the transport system; it is denoted through mathematical symbols. The model were derived to express the variable function at each considered condition base on the behaviour of the microbes, the expression detailed the function of all the variables as it is expressed mathematical in the governing equation, this expression will be derived to monitor the rate of salmonella through fluid pressure in lateritic and silty formation in coastal area of Port Harcourt.

3.0 Governing Equation

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

Taking Laplace transformation of (1)

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

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

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

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

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

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

The governing equation to monitor the rate of salmonella through fluid pressure were transformed to Laplace, this concept were to express the variables in terms of determining their various functions known as product, the transformation were expressed from equations (2) to (7) where initial concentration of the microbes were expressed.

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

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

$$\left\|SP_{(t)} - P_{(0)} + Pg\left(SP_{(t)} - P_{(0)}\right)\right\| = QPz \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (8)$$

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

The parameter were substituted into the governing equation as it has been transformed to Laplace, these put the variables at the proper position where various functions as it influence the transport system will be monitored. These expressions were found in equations (8) and (9).

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

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

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

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

Further expressions were done to monitor the system with respect to time generated in equation (10). Since the system is moving on the direction of flow through the micropore on the soil, it will definitely vary either low or high and are influenced by permeability [k], this condition were considered as it is expressed in equation (11).

Rearranging (11), yields

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

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

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

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

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

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

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

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

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

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

Rearranging it the way that the flow will be monitored under the influence of porosity and other significant parameters, which are relevant, were integrated that yield an expression from equation (12) to (19).

Hence in any direction *x*, we have

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

Considering the transport of the microbes on the distance travelled, it yield an expression in equation (20), this was to monitor the rate of concentration at every stratum and the behaviour of the microbe on those formations it has migrated.

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

Again, we consider (10) so that we have

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

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

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

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

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

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

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

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

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

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

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

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

Combining equation (28), we have

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

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

To discretise the variables and see their ratio of influence on the transport system this were monitored as it is expressed from equations (22) to (30).

Subject to the relation of time which is equal to distance divided velocity of transport were expressed to determine the rate of fluid pressure that influence the microbial transport to groundwater aquifer, this expression were integrated as final derived mathematical model expression were obtained in equation (31).

The equation derived that generated the model, in equation (31) considered all the significant parameters that have influences on the rate of salmonella in migration from lateritic to silty formation; it has expressed the shallow aquiferous zone degrees of fast contaminant migration. As since the study area is a coastal aquifer deposition, there is no doubt that such fast migration of microbial transport will be predominant, because their silty formation were confirmed to be aquiferous deposition known to unconfined bed.

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

The study is imperative because it has detailed the behaviour of E.coli transport influenced by pressure fluid, and the cause of high degree of fluid pressure were expressed, this has shown the rate of fast migration of microbial transport in coastal aquifers, the rate of salmonella migration at various formations within a short period has been expressed, the model has streamline the influence of fluid pressure in coastal aquifer as it has shown the behaviour through the degree of E.coli migration in the study area.

4. Conclusion

Salmonella transport in soil and water environment has been confirmed as one of the most threats of water pollution; regeneration of microbes through spreading of biological waste has been confirmed to constitute the source of pathogen to groundwater. Aquifer, Furthermore, the dumping of waste indiscriminately is a serious source that constitutes microbial pollution from soil to groundwater. To monitor the rate of these source of pollution, mathematical equations were developed, the established system produce governing equation that will monitor the rate of this microbial specie to ground water aquifer, the model developed from the governing equation will be applied to establish a baseline for experts in the field of water resources to understand the source of this pollution, through the behaviour of the microbes, the model also will be able to monitor the source and fast migration of the microbes, this will assist professional to be able to manage this type of pollution source through the established derived model for the salmonella migration to groundwater aquifer in the study location.

REFERENCES

[1] Huysman, F. and Verstracete, W. (1993a) Soil Biochem 25, 1, 83.

[2] Huysman, F. and Verstracete, W. (1993a) Soil Biochem 25, 1, 91.

[3] Lance, J. C. Gerba, C. P. and Cherry, J. A. (1985). Applied Environmental Microbiology 50, 383.

[4] Lance, J. C. Gerba, C. P. and Cherry, J. A. (1985). Environmental Science, Technology 19, 384.

[5] Dean, D. M. and Foran, M. E. (1990a). The effect of farm liquid waste application on receiving water quality interim.Report, submitted by Ausable Bayfield Conservation Authority to the Research Management office of the Ontario Ministry of the Environment. April.

[6] Dean, D. M. and Foran, M. E. (1990a). The effect of farm liquid waste application on receiving water quality interim.Report, submitted by Ausable Bayfield Conservation Authority to the Research Management office of the Ontario Ministry of the Environment.

[7] Fleming, R. I., Dean, D. M. and Foran, M. E. (1990). Effect of manure spreading on the drainage: Water quality, proceeding of the 6th international symposium of agricultural and food processing wastes, Chicago Illinois, p. 385.

[8] Palmate, G. A., Mclean, D. E., Walsh, M. J., Kutas, W. L., Janzen, M. e. and Hocking, D. E. (1989). Toxicity Assess, 4, 377.

[9] Khatel, R., Reddy, K. R. and Overcash, M. R. (1980). Journal of Hydrology 72, 149.

[10] Corapcioglu, M. Y. and Haridas, A. (1984). Journal of Hydrology 72, 149.

[11] Tim, U. S. and Mostaghimi, S., Dulaha, T. A. (1988). Modelling the movement of persistence of bacterial and virus in porous media. A20 paper No. 88-2627, St. Joseph M.

[12] Tim, U. S. and Mostaghimi, S. (1991). Groundwater 29, 251.

[13] Chen, M. (1988). Water, Air and Soil pollution, 37, 407.

[14] Keswick, B. H., and Gerba, C. P. (1980). Science Technology 14, 1290.

[15] Keswick, B. H., Wang, D. and Gerba, C. P. (1982). Groundwater 20, 142.

[16] Stewart, L. W. and ReneauJr, R. B. (1981). J. Environment Quality 10, 528.

[17] Virasaghaven, T. (1978). Water, Air and soil pollution 9, 355.

[18] Gerba, C. P. and Bilton, G. (1984). Microbial pollutants: their survival and transport pattern t groundwater in G. Bilton and C. P. Gerba (eds) Groundwater pollution microbiology, John Wiley & sons Inc, New York, pp 65-88.

[19] Gerba, C. P. and Keswick, B. H. (1981). Survival and Transport of enteric viruses and bacterial in groundwater: in W. Van Duijvenbooden, P. lasberge and Hvan l Lelveld (eds) studies in environmental science,Elsevier scientific Publication Co. The Netherlands pp. 511 – 515.