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Research article

MODELING THE TRANSPORT OF BACILLUS IN LINEAR PHASE CONDITION IN HETEROGENEOUS UNCONFINED AQUIFERS IN AHOADA EAST, RIVERS STATE OF NIGERIA

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Abstract

Modeling the transport of bacillus in stationary phase condition in heterogeneous unconfined aquifer has been expressed. The model was derived through generated governing equations, the expressions were derived in phases, and this is to monitor the system by considering all the parameters that influenced the bacillus migration in soil and water environment. The formations under study are few areas that were confirm to deposit heterogeneous formation under the influence of lacustrine in deltaic environment. These influential parameters were considered in the system when the governing equations were formulated, the equations were derived and it generated several model at different phase in the system. This is in accordance with the behaviour of the microbes and other formation characteristics. The model were integrated together were the final model were generated, the model express all the parameters base on the behaviour at different formations, the expressed model will definitely monitor the migration of bacillus in unconfined aquifer, experts will find the model useful because the stationary phase conditions are found to increase the concentration of the microbes, unless there are an inhibitions in the aquiferious zone.

Keywords: Modeling transport, bacillus, linear phase, and heterogeneous unconfined aquifers

1. Introduction

The influential factors affecting the survival of pathogens in water, particularly microorganisms and viruses, include temperature, pH, dissolved oxygen, water hardness, presence of organic material, exposure to sunlight, the presence of other micro-organisms and water conductivity (O'Brien & Newman, 1977; Lund, 1978; Melnick & Gerba, 1980; Davies-Colley et al. 1994). Protozoan cysts stay alive over a wide range of pH values and are resistant to osmotic pressures. *Cryptosporidium* oocysts can stay alive for over twelve months in isotonic solutions in the laboratory and may remain viable for long periods in aquatic environments (Smith et al. 1991). The major factor affecting cyst and also Helminth egg survival in water is temperature, with higher temperatures resulting in faster death (Feachem et al. 1983; O'Donohue, 1995). Water can carry pathogens over quite large distances. In a study of the Zambezi River, bacteria were still detected 18.6 km downstream from the source of contamination at levels at 1.4 x 103 *E. coli*/100 ml (Feresu & Van Sickle, 1990). Lund (1978) made similar observations in tropical waters. Virus survival in the environment can be increased through adsorption to organic or soil particles where they are protected from environmental influence (Gerba et al. 1975; Geber 1984 Feachem et al. 1983; Hoff & Akin 1986). Factors that influence adsorption of the viruses in soil and therefore their survival include the nature of virus, the presence of cations, presence of particulate organic material, composition of the soil and pH (Bagdasaryan, 1964; Gerba et al. 1975; Melnick & Gerba, 1980; Gerba, 1984). Low pH values will aid in the adsorption of viruses while high pH will result in virus release from adsorbed particles (Gerba et al. 1975), In general, viruses are most stable at neutral pH (England, 1982). A more detailed discussion on the adsorption of viruses can be found in Gerba (1984). Inactivation of viruses in soil has been in part attributed to the presence of aerobic micro-organisms, which can degrade the virus particles or interfere with viral adsorption (Hurst et al. 1980; Hurst, 1988). The moisture content of soil will also affect virus survival, with virus particles being inactivated by desiccation (Bagdasaryan, 1964; Yeager & O'Brien, 1979a; Straub et al. 1993). One of the mechanisms involved in poliovirus inactivation during drying seems to be the dissociation of the viral capsid and genome (Yeager & O'Brien, 1979b). Increasing temperatures will decrease the survival times of viruses in soil (Yeager & O'Brien, 1979a; Hurst et al. 1980; Straub et al. 1993). The most important parameters controlling virus persistence in the environment are temperature and desiccation.

2. Theoretical Background

Bacillus is one the establish microbes deposit from biological waste through the activities of man in the study area, the contaminant found in ground is serious threat human settlement in the area. This situation implies that several people may have suffered from water related diseases from these source of pollutant without knowing the foundation, such results from a comprehensive laboratory examinations were appropriate to assess water excellence of the surroundings, the consequence from water investigation is of serious concern to environmental health experts and government agencies in environmental health sector, the consequence from the ground water investigation shows that in some location the pollutant dilapidation were in variable, this implies that microorganisms in some situation are experiencing degradation, but the soil structure this microbes deposit were not known, at various area the samples were collected for scrupulous examination, the unidentified information is the fundamental cause of the contamination in the study area, consequently it is imperative that the source of the contamination should be identified, thus fine permanent solution to the problem, in other to solve the threat of life, mathematical model was appropriate to resolve this hazard, the model were generated through the formulation of governing equation, the equation were generated base on the various information generated from hydrogeological studies, the study expressed the geological formation of the area, the structural deposition of the formation, includes geomorphology and geochemistry of the formation, the study highlighted the variations of aquiferious zone and static water level ,further studies are to determine the degree of porosities, void ratio, and permeability. The formulated equation considered all this variables in the system

3. Governing Equation

$$C_{(x)} \frac{\partial v(x)}{\partial t} \frac{-V}{t} \left[C(x) \frac{-x\partial c(x)}{\partial t} \right] - KC(x)\frac{V}{t}(x) = \frac{V\partial c(x)}{\partial t} \quad \ldots\ldots\ldots \quad (1)$$

The governing equations express the migration of bacillus in the study area, generated equation expressed microbial situation in the structural deposition, the developed equations were derived in phase based on linear phase condition of the microbes, this expressed the behaviour under the influence of the stratification of the formation. Exponential phase of the microbes are influenced by numerous parameters in soil and water environment, therefore, the generated governing equation were derived considering the condition fluctuation in degradation, this is to ensure that the conditions expressed in linear phase were considered in the system.

If $\frac{\partial v}{\partial t} + \frac{V\partial c(x)}{\partial t}$ and $C_{(x)} \frac{-\partial v(x)}{\partial t} = \beta$ ………………… (2)

Such that $\frac{V\partial c(x)}{\partial t} + \frac{V}{t}C(x) \frac{-x\partial c(x)}{\partial x} - KC(x)\frac{V}{t}(x) = \beta$ …… (3)

We have $\frac{V\partial c(x)}{\partial t} = \frac{-V}{t}C(x) \frac{-x\partial c(x)}{\partial x} - KC(x)\frac{V}{t}(x) - \beta$ ……… (4)

By transformation of eqn. (4) we have

$$C_{(x)} = T_x$$

It implies that $\frac{\partial c(x)}{\partial t} = T^1 x$ ………………………………………… (5)

Obtaining it from separation of variables we have

$$\frac{\partial c(x)}{\partial t} = Tx^1$$

Substituting in eqn. (4.) we have

$$V\left(T^1 x\right) = \frac{-V}{t} Tx^1 - Tx\frac{\partial v(x)}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Expanding on equation (4.227) we have

$$VT^1 X \quad \frac{-V}{t} TX^1 - Tx\frac{\partial v(x)}{\partial t} \quad \ldots\ldots\ldots\ldots \quad (7)$$

Dividing equation (7) by *Tx* we have

$$TX\frac{\frac{\partial v(x)}{\partial t}}{TX}\ \frac{-V}{t}\ \frac{TX-XTX^{1}}{Tx}-KTX\frac{\frac{VC(x)}{t}}{TX}\ \frac{-VT^{1}X}{TX}\ \ldots\ldots\ldots\ldots \tag{8}$$

This implies that

$$\frac{\partial v(x)}{\partial t}\ \frac{-V}{t}\left[1-\frac{X^{1}}{X}\right]\frac{-KV(x)}{t}\ \frac{-VT^{1}}{T}\ \ldots\ldots\ldots\ldots\ldots\ldots \tag{9}$$

But if $\frac{V\partial c(x)}{\partial t} = \lambda^{2}$

We have

$$\frac{\partial v(x)}{\partial t}\ \frac{-V}{t}\left[1-\frac{X^{1}}{X}\right]\frac{-KV(x)}{t}\ \frac{-VT^{1}}{T} = \lambda^{2}\ \ldots\ldots\ldots\ldots \tag{10}$$

If $\frac{V\partial c(x)}{\partial t} = \lambda^{2}$ …………… (11)

Solving it term by term we have

$$SV_{(s)} - V_{(o)} = \lambda^{2}\ \ldots\ldots\ldots\ldots \tag{12}$$

$$V_{(o)} = C_{y_1}$$

$$SV_{(s)} - C_{y_1} = \lambda^{2}\ \ldots\ldots\ldots\ldots\ldots\ldots \tag{13}$$

$$V_{(s)} = \frac{\lambda^{2} + C_{y_1}}{S}\ \ldots\ldots\ldots\ldots\ldots\ldots \tag{14}$$

Since Laplace inverse of I/S = 1 we obtain

$$V_{t} = \lambda^{2} + C_{y_1}$$

$$\lambda^{2} = \frac{V_{t}}{C_{y_1}}$$

$$\boxed{T_{(t)} = VC_{y_1}\ell^{\frac{\lambda^{2}}{V}t}}\ \ldots\ldots\ldots\ldots\ldots\ldots \tag{15}$$

The derived models on these phases are subjected to velocity of transport; this is considered as the stabilization of the system. This notion displayed velocity of transport, and generated more influences with respect to time from the point of discharge or the point of indiscriminate dump leaching down to the point where the movement were influenced by an average degree of porosity, under the influence of exponential condition. The microbes at this conditions will increasingly migrate to where it may be favourable for them, because the movement of the microbes and substrate deposition may leach at the same whereby there is constant increase of microbial inhabitants. This condition are mostly depends on formation of the soil, develop a fracture on the stratification; the lithology will be influenced on the linearized transport of the microbes with higher concentration.

$$\frac{V}{t}\,1 - \frac{X^{1}}{X} \quad \text{........................} \quad (16)$$

$$X_{t} = \frac{V}{t} C_{y_2} \ell^{\frac{\lambda^2}{V}t} \quad \text{..} \quad (17)$$

$$K\frac{V(x)}{t} = \lambda^2 \quad \text{...........................} \quad (18)$$

$$V_{(x)} = K\frac{V}{t} C_{y_3} \ell^{\frac{\lambda^2}{V}t} \quad \text{...........................} \quad (19)$$

This two expressed model were generated at different conditions, the developed model in (17) express the concentration under the influence of distance, velocity and time displayed there functions fast fine concentration were found interact with the parameter that stabilizer the system in exponential phase, this expression where able to monitor the progressive condition to a point were the microbes experienced stationary condition, while the established model in (18) displayed the function of velocity impact in transport system in with respect to distance, the influence permeability of the formation were expressed under the influence of velocity of transport, but to an extend the transport progress to were the formation subjected the microbial migration to be immobile in some stratum.

$$\frac{VT^{1}}{T} = \lambda^2 \quad \text{.....................} \quad (20)$$

$$VT^{1} = \lambda^2 T \quad \text{........................} \quad (21)$$

Let $T_{(o)} = 0$

$$VT^{1} - \lambda^2 T = o \quad \text{........................} \quad (22)$$

$$V(ST_{(s)} - T_{(o)} - \lambda^2 T(s) = 0 \quad \text{.....................} \quad (23)$$

Considering the boundary condition we have

$$T_{(o)} = C_{y_4}$$

Where C_{y_1} is the initial concentration?

$$V(ST_{(s)} - C_{y_4}) - \lambda^2 T_{(s)} = 0 \quad \text{........................} \quad (24)$$

$$VST_{(s)} - VC_{y_4} - \lambda^2 T_{(s)} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (25)$$

$$(VS - \lambda^2)\, T_{(s)} = VC_{y_4} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (26)$$

$$T_{(s)} = \frac{VC_{y_4}}{Vs - \lambda^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (27)$$

$$VS - \lambda^2 = 0$$

$$VS = \lambda^2$$

$$S = \frac{\lambda^2}{V} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (28)$$

$$\boxed{C_{(x)} = VC_{y_4}\, \ell^{\frac{\lambda^2}{V}t}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

The expressed model in (29) involved velocity in this phase more like other conditions, the rate of concentration are determined by the velocity of transport progressively from the region were degree of porosity are deposit homogeneously to were is found to be heterogeneous in the strata,

The transport processes under exponential conditions express its relation with the stabilizer of the system. The formation may experienced low porosity thus the microbes become immobile in there transport behaviour, this implies that the permeability decrease in degree of deposition in the strata.

Since we have

$$\frac{\partial v(x)}{\partial t}\ \frac{-V}{t}\left[1 - \frac{X^1}{X}\right] - \frac{KV(x)}{t}\ \frac{-VT^1}{T} = \lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

If we let $C_{(x)} = T_{(x)}$ we have

$$\frac{\partial v(x)}{\partial t}\ \frac{-V}{t}\ 1 - \frac{X^1}{X} - \frac{KV(x)}{t}\ \frac{-VT^1}{T} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (31)$$

Integrating both sides gives

$$\boxed{VC_{y_1} = VC_{y_4}\, \ell^{\frac{\lambda^2}{V}t} = \frac{K}{V} C_{y_2}\, \ell^{\frac{\lambda^2}{V}t}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (32)$$

Another expressed model through another phase of microbial behaviour were considered in the system, the velocity and concentration integrated together to monitor the microbes in a condition were permeability determined the rate of velocity of solute, the concentration at these conditions change with respect to change in rate of velocity of flow in the strata, the condition are base on the deposition of variation in formation characteristics. Further more, the expressed model in these phaseare influenced by this variation of the stated parameters in the system from exponential condition to immobile condition under the influenced of formation variables.

Therefore

$$C_{(x)} = VC_{y_1} \ell^{\frac{\lambda^2}{V}t} = \frac{KV}{V} C_{y_3} \ell^{\frac{\lambda^2}{V}t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (33)$$

But if $\lambda^2 = \frac{Vt}{Cy_1}$

$$C_{(x)} = VCy_1 \ell^{\frac{Vt}{Cy_1}} = \frac{V}{t}Cy_2 + K\frac{V}{t}Cy_3 + Cy_4 \ell^{\frac{Vt}{V}t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (34)$$

$$C_{(x)} = VCy_1 \ell^{\frac{Vt}{Cy_1}} = \frac{V}{t}Cy_2 + K\frac{V}{t}Cy_3 + Cy_4 \ell^{\frac{\lambda^2}{V}t} \quad \ldots\ldots\ldots \quad (35)$$

Three established models from (33), (34) and (35) expressed their role at various accomplishments, based on different behaviour in various formations at different depths. Equation (33) expressed its model where by velocities are dominant in the system, the concentration with respect to the rate of speed of transport were more noticeable in equation (34), the parameters establish the rate of other variables through velocity of flow. This stabilizes the structure; it displayed its purpose by ensuring that there is a relation between the concentration and the rate of velocity of the microbes in another direction. This expression were under the influence of time from were the pollutant are deposited. The expression in (34) maintained similar condition, but were found to relate the concentration with respect to distance, fast migration of the microbes were found to increase compared the level of migration in (33), this implies that the movement of the microbes developed higher increase, the soil structure at this level deposit higher porosity thus producing more microbial increase that determine the rate of concentration, the expressed model in (34) shows the rate degree of permeability of the soil, this determined the rate of velocity of flow that transport the pollutant. The concentration increase base on the rate of substrate and other influence that deposit on the formation. Therefore the expressions at these levels influence the rate of concentration of the microbes in exponential level, the formation experienced variation of formation characteristics, the contaminants also shows the decrease of permeability thus influence velocity of flow, this condition change the transport process of the microbes thus establishing mobile state of the microbes. Times were found to maintain it rate base on the degree of porosity and velocity of transport.

The developed model in equation (35) is the parameters that are influential in this phase expressed its fluctuation from its exponential condition to stationary condition. The expressed model at this phase implies that the parameters coordinated themselves together, by relating their functions thus, the behaviour of the microbes in terms of degradation, this depends on the deposition of the substrate in the formation, the behaviour of the microbes depend on this stated condition.

$$C_{(x)} = T_x = T_x \, X_t$$

$$C_{(x)} = \left(VCy_1 \, \ell^{\frac{V^2}{V}t} \right)\left(\frac{V}{t} Cy_2 \, \ell^{\frac{V^2}{V}t} \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (36)$$

The transport of the microbes continues to transform their behaviour base on the deposition of rate numerous dominant variables that may be permissible to them in immobile condition, but the study focuses on the linear phase of the microbial deposition in soil and water environment, therefore the condition of its linear phase implies that on the process of migration, to an extend there is change in stratification were degree of permeability degrees and influence the microbial migration to immobile state. Such condition substrates were found to deposit at high degree on the formation, this implies that the substrate will definitely increase there population. These condition implies that at linear of phase the microbes' are expected to increase under the influence of substrate deposition, but non are deposited the population may reduce due to change in formation characteristics or inhibition deposition in the formation, So equation (36) microbes may maintained in there transport to ground water aquifers through change if stratification when they experience variation of flow.

$$C_{(x)} = \left(VCy_1 \, \ell^{\frac{V^2}{V}t} \right)\left(\frac{KV}{t} Cy_3 + Cy_4 \, \ell^{\frac{V^2}{V}t} \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (37)$$

The model in (37) is the final model equation the expression the linear phase condition of microbial transport in soil and water environment, linear phase condition were express mathematical to monitor bacillus behaviour in mobile phase, the developed governing equation were derived in stage, this to descretized several influential parameters so that there function on the microbial behaviour will be express, the express equation generated numerous model considering several phase, thus the behaviour of the microbes in there transport process.The dominant parameters that may develop mobile of the microbes were expressed in the system thus the model express diverse condition base on the considered parameters that cause mobile condition, this express there function to the optimum level, the benefit of the model to be developed in phases is that it produced several behaviour of the microbes under the influence of formation variable and its characteristics. This is to ensure that the conditions that cause immobile in microbial transport process are expressed, while migrating to ground water aquifers, this condition to monitor the rate of migration in other to express there functions, finally all the models were coupled together to developed the final model equation that will monitor bacillus in linear phase condition in soil and water environment.

4. Conclusion

The developed equation that govern the migration of bacillus in heterogeneous unconfined aquifers has been mathematical expressed, the governing equation s were formulated by considering the parameters that are dominant to migration and linear phase of bacillus in soil and water environments. The generated equation were express in stages, the models were expressed in phases in accordance with their behaviour thus the variation of soil formation, the parameters that were influential in those condition were considered so that it will express its functions to the maximum in the system, this is to ensure that the behaviour of the microbes at each phase are full represented in the expressed model at every phase in the system. The models were finally coupled together to express the final model that will monitor the bacillus phase in heterogeneous unconfined aquifers.

References

[1] Bagdasaryan, G.A., 1964. Survival of viruses of the enterovirus group (poliomyelitis, echo, coxsackie) in soil and on vegetables. Journal of Hygiene, Epidemiology, Microbiology and Immunology, **8**, 497- 505.

[2] Davies-Colley, R.J., Bell, R.G. and Dennison, A.M., 1994. Sunlight inactivation of enterococci and fecal coliforms in sewage effluent diluted in seawater. Applied and Environmental Microbiology, **60**, 2049-2058.

[3] Feresu, S.B., and Van Sickle, J., 1990. Coliforms as a measure of sewage contamination of the River Zambezi. Journal of Applied Bacteriology, **68**, 397-403.
Gerba, C.P., 1984. Applied and theoretical aspects of virus adsorption to surfaces. Advances in Applied Microbiology, **30**, 133-168.

[4] Gerba, C.P., Wallis, C. and Melnick, J.L., 1975. Fate of wastewater bacteria and viruses in soil. Journal of the Irrigation and Drainage Division, **101**, 157-174. (abs.)

[5] Hurst, C.J., 1988. Influence of aerobic micro-organisms upon virus survival in soil. Canadian Journal of Microbiology, **34**, 696-699.

[6] Hurst, C.J., Gerba, C.P. and Cech, I., 1980. Effects of environmental variables and soil characteristics on virus survival in soil. Applied and Environmental Microbiology, **40**, 1067-1079.

[7] Lund, E., 1978. The survival of viral pathogens in water and waste in the tropics. Progress in Water Technology, **11**, 73-79.

[8] Melnick, J.L. and GERBA, C.P., 1980. The ecology of enteroviruses in natural waters. CRC Critical Reviews in Environmental Control, **10**, 65-93.

[9] O'Brien, R.T. and Newman, J.S., 1977. Inactivation of polioviruses and coxsackieviruses in surface water. Applied and Environmental Microbiology, **33**, 334-340.

[10] O'Donohue, P.J., 1995. Cryptosporidium and Cryptosporidiosis in man and animals.Internat. J. Parasitol., **25**, 139-155.

[11] Smith, H.V., Grimason, A.M., Benton, C. and Parker, J.F.W., 1991. The occurrence of *Cryptosporidium* spp. Oocysts in Scottish waters, and the development of a fluorogenic viability assay for individual *Cryptosporidium* spp. Oocysts. Water Science Technology, **24**, 169-172.

[12] Yeager, J.G. and O'Brien, R.T., 1979a. Enterovirus inactivation in soil. Applied and Environmental Microbiology, **38**, 694-701.

[13] Yeager, J.G. and O'Brien, R.T., 1979b. Structural changes associated with poliovirus inactivation in soil. Applied and Environmental Microbiology, **38**, 702-709
Hoff, J.C. and Akin, E.W., 1986. Microbial resistance to disinfectants: mechanisms and significance. Environmental Health Perspectives, **69**, 7-13.

[14] Reddy, K.R., Khalfft, R. and Overcash, M.R., 1981. Behaviour and transport of microbial pathogens and indicator organisms in soils treated with organic wastes. J. Environmental Quality, **10**, NO. 3, 255- 266.