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Research article

MODELING EXPONENTIAL PHASE MIGRATION OF EDWARDSIELLA IN HOMOGENEOUS SILTY AND FINE SAND FORMATION AQUIFERS IN COASTAL AREA OF BUGUMA, RIVERS STATE OF NIGERIA

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Abstract

Modeling the movement of Edwarosiella in progressive phase condition in homogenous silty and fine sand formation has been evaluated. The model was derived through formulated governing equation, the expressions were derived in stages, this is to monitor the system by considering all the parameters that influence the migration of Edwarosiella in soil and water environment. The formations under study area are predominant with homogeneous formations; significant states were considered in the system. When the governing equations were formulated, the equations were derived and it generated numerous models at different phase in the system. This is in accordance with the behaviour of the microbes and other formation characteristics. The model were incorporated together to produce final model that will monitor the transport of Edwarosiella in silty and fine sand formation in the study area. The model express all the parameters based on the behaviour at different formations, the expressed model will definitely monitor the migration of Edwarosiella in unconfined aquifer, experts will find the model valuable because the progressive state are found to increase the concentration of the microbes unless there are inhibitions in aquiferious zone.

Keywords: modeling exponential migration, Edwardsiella, and silty and fine sand formation

1. INTRODUCTION

Anthrax is known to be acute bacterial infection of primarily herbivores, which is infectious to humans. The etiologic agent, *Bacillus anthracis*, is a gram-positive spore developing rod shaped microbes. Animals become contaminated by ingesting spores or perhaps by being bitten by flies that have fed on an infected animal or carcass (Ebedes, 1976). Contaminated animals are normally found dead as death can happen within 24 hours. (Whitford and

Hugh-Jones, 1994). Anthrax can be established universal affecting wildlife, livestock, and humans. During epidemics in 1959/60 and 1970 in the Kruger National Park, South Africa, anthrax deaths numbered in the thousands (De vas 1976). Livestock luggages are identified to contribute to human cases through the cutaneous gastrointestinal and inhalation route. In 2000, the first gastrointestinal cases were reported in the United States after the family ate beef from an infected carcass (Dragon and Rennie 2001: Pamala, 2002).Although environmental contamination with *B. anthracis* spores occurs because of wildlife and domestic livestock cases, the degree or level of pollution from each case is unknown. Anthrax spores are known to persevere in the surroundings for years and are opposed to ecological factors (Turnbull 1996). Spores may be found in soil contaminated by diseased animals or in diseased animal products such as hair, wool, hides, and bones (Beyer, et al 1995, Lindedeque and Turnbull 1994). Very little research has been done on anthrax spore survival under natural conditions.

Eight hundred and eighty four million people were estimated from WHO to lack access to enhanced water sources, and estimated 2.6 billion populace do not have access to enhanced sanitation (UNICEF and WHO 2010a UNICEF and WHO 2010b UNICEF and WHO 2010c). In 2000, it is confound that Water Supply and Sanitation joint Council (WSSCC), a universal multi-partner organization intended at enhancing entrance to safe water and hygiene, established three precise targets for water supply and sanitation: 1) decrease the amount of people lacking access to hygienic sanitation facilities by one half by 2015, 2) decrease the amount of people without access to a sustainable source of quality drinking water by one half by 2015 (where superiority water is defined as assembly the WHO guidelines for safe drinking water), and to provide water, sanitation and hygiene for all by 2025 where sanitation was defined as full coverage of hand washing, safe disposal of feces, as well as safe water handling and storage (UNICEF and WHO 2000). eight goals has been confound to have been set by united nations to achieve this Millennium Development Goals (MDGs) the aim is to increase equality and decrease poverty universal, and among these, was the goal is to decrease the number of people who do not have access to safe water and improved sanitation by half by 2015 (UN 2011). Ever since 2000, exponential coverage of 7 and 10% worldwide for superior sanitation and water access respectively has occurred. However, if radical improvements towards the MDGs are not prepared, then in 2015 an predictable 2.7 billion people were confirm have access to enhanced sanitation, more so 672 million will be lacking better drinking water sources, reaching the MDG for water access and missing the sanitation target by 13% (UN 2010; UNICEF and WHO 2010c).

The load of lack of access to secure water sources and enhanced hygiene falls heavily on people in developing nations and is even a more ordinary trouble for people living in rural areas compared to those living in urban environments (UNICEF and WHO 2010c). Rural populations account for around 84% of the people lacking access to improved water sources and sanitation services (UNICEF and WHO 2000). The WHO defines enhanced drinking water sources as those with knowledge that is most likely to deliver safe water to persons, such as family relations to piped water, public standpipes, boreholes, protected wells, and rainwater catchments (WHO 2004). It is significant to note that insecure wells, springs, water sold from vendors and tanker trucks fall under the heading of "unimproved water sources." (WHO 2004).Pathogens are frequently multiply in low concentrations into water supplies making them hard and costly to detect. But some microorganisms can be used to indicate pathogen existence in water; however the association is not always a straight connection (Ashbolt et al. 2001; EPA 2009). Ashbolt et al. (2001) describe three types of microbial indicators: 1) process indicators, 2) fecal indicators, and 3) index organisms. Microbes are deposited in intestines of warm-blooded mammals and are discarding into the environment in excreta (Ashbolt et al. 2001; EPA 2010). Total coliform bacteria may occur in human intestines; these sources of contaminants are found in animal excreta, soil, and from other man made activities (EPA 2010). Total coliforms are considered process indicators and used for drinking water analysis confirmed to notice the presence of pollutants; however they do not precisely compare to pathogen pollution. The existence of total coliforms in treated drinking water indicates incomplete treatment, treatment failure, or post-treatment contamination.

Fecal coliforms and *E. coli* are more closely linked to fecal contamination from warm-blooded mammals than total coliforms, although both can be found in the environment from non-fecal sources (Ashbolt et al. 2001; EPA 2010). Fecal coliforms and *E. coli* are less useful as environmental indicators of water quality due to the possibility of non-fecal origins, but they are generally good indicators of fecal contamination in drinking water (EPA 2010). *E. coli* is not only recommended as an indicator of fecal contamination, but can also be used as an index organism along with Enterococci (a fecal streptococci bacteria), because their presence often occurs with *Vibrio cholerae*, *Salmonella*, *Cryptosporidium parvum*, and other water-borne bacteria shed into the environment along with excreta (EPA 2010; NRC 2004, Stephen 2008).

2. THEORETICAL BACKGROUND

Edwarosiella is one of the microbes found to deposit on biological waste in the course of mans behavior in the study area; the pollutant found in ground is severe menace in human settlement in the area. This condition implies that numerous people may have suffered from water related diseases from this foundation of contaminant without knowing the basis; such consequences from a comprehensive laboratory examination were suitable to assess water quality of the environment. The outcome of the water examination is a serious concern to environmental health, thus experts and government agencies in environmental health sector should develop a conceptual frame work to stop this menace, the outcome of the ground water investigation shows that in some localities the contaminant experience exponential phase, this implies that microorganisms in some situations are experiencing increase in microbial population, but the soil formation these microbe deposit were not known, at various areas, Samples were collected for thorough investigation, the unidentified information is the primary cause of the pollution in the study area, consequently it is essential that the foundation of the contamination should be identified, thus fine lasting solution to the problem. In other to solve the menace of life, mathematical model was suitable to determine this hazard, the model were through the formulated governing equations, the equation were generated based on the variety of information generated from hydrogeological studies, the study expressed the geological formation of the area, the stratification of the formation, together with geomorphology and geochemistry of the formation, the study highlighted variations of aquiferious zone and static water level. More so, studies on degree of porosities, void ratio, and permeability were expressed in the system. The designed governing equation considered all these variables in the system.

3. GOVERINING EQUATION

$$C_{(x)}\frac{\partial v(x)}{\partial t} - D_A v^2 - \partial c(x) = \frac{V\partial c(x)}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The governing equations express the migration of Edwarosiella in the study area, the formulated equation express the microbial condition in the structure of the equation, the developed equation were derived in stages base on progressive phase condition of the microbes, this express the behaviour under the influence of the geological formation. Exponential stage of the microbes are influence by several parameters in soil and water environment, therefore the generated governing equation were derived considering these condition to ensure that the conditions are expressin the system.

If $\frac{\partial x}{\partial t} = \frac{vc(x)}{\partial t}$

And $C_{(x)}\frac{\partial v(x)}{\partial t} = \beta$ $\quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$

we have $\frac{V\partial c(x)}{\partial t} + D_A v^2 \frac{\partial c(x)}{\partial x} = \beta$ $\quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$

Such that

$$\frac{V\partial c(x)}{\partial t} = D_A v^2 \frac{\partial c(x)}{\partial x} - \beta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

By transformation of (4) we have

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

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

It can be obtained from separation of variables

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

Substituting in (4) we have

$$V\left(T^1 x\right) = D_A v^2 \; Tx^1 - Tx\frac{\partial v(x)}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Expanding further we get

$$VT^1x \;=\; D_A v^2 \; Tx^1 \;-\; Tx\frac{\partial v(x)}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (6)$$

Dividing equation (6) by *Tx* we have

$$\frac{VT^1x}{Tx} \;=\; D_A v^2 \frac{Tx^1}{Tx} \;-\; Tx\frac{\partial v(x)}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (7)$$

Then it implies that

$$\frac{VT^1}{T} \;=\; D_A v^2 \frac{x^1}{x} \;-\; \frac{\partial v(x)}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (8)$$

If $\frac{v\partial c(x)}{\partial t} \;=\; \lambda^2$

We have

$$\frac{VT^1}{T} \;=\; D_A v^2 \frac{x^1}{x} \;-\; \frac{\partial v(x)}{\partial t} \;=\; \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (9)$$

Solving term by term, we have

$$\frac{VT^1}{T} \;=\; \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (10)$$

$$VT^1 \;=\; \lambda^2 T \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (11)$$

Let $T_{(o)} \;=\; 0$

$$V(ST_{(s)} - T_{(o)}) \;-\; \lambda^2 T_{(s)} \;=\; 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (12)$$

Considering the boundary condition, we have

$T_{(o)} \;=\; C_1$

Where C_1 is the initial concentration?

$$V(ST_{(s)} - VC_1) \;-\; \lambda^2 T_{(s)} \;=\; 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (13)$$

$$VST_{(s)} - VC_1 \;-\; \lambda^2 \; T_{(s)} \;=\; 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (14)$$

$$VST_{(s)} \;-\; \lambda^2 T_{(s)} \;=\; VC_1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (15)$$

$$(Vs - \;\lambda^2)\; T_{(s)} \;=\; VC_1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (16)$$

Then $T_{(s)} \;=\; \frac{VC_1}{VC_1} \;-\; \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (17)$

$$Vs \;-\; \lambda^2 \;=\; 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (18)$$

$$Vs = \lambda^2$$

$$S = \frac{\lambda^2}{V} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

$$T_{(s)} = VC_1 \, \ell^{\frac{\lambda^2}{v}t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

The resultant model on these phase are subjected to time of transport, this considered λ^2as the stabilization of the system, this ideas displayed in the transport system, this parameter stable the system and generate more influence with respect to time from the point of discharge or the point of indiscriminate dump leaching down to the point were the movement were influenced by an average degree of porosity, this were experienced under the influence of exponential condition. The microbes at these conditions will progressively transport to may be faviourable for them, because the movement of the microbes and substrate deposition will definitely depend on leaching rate at thus regeneration causing constant increase of microbial inhabitants.

$$D_A v^2 \frac{x^1}{x^1} = \lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

Where $X_{(o)} = C_2$

$$X_{(t)} = D_A v^2 C_2 \, \ell^{\frac{\lambda^2}{D_A v^2}t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

This two express model were generated at different conditions, the developed model in (22) express the concentration under the influence of distance, dispersion and time displayed there functions very well, concentration of the microbes were found to interact with the parameters, but the is system stabilizer were able to express there condition in exponential phase, the developed model where able to monitor the progressive condition to a point were the microbes experienced increase in microbial population, while the established model in (20) displayed the function of velocity impact in transport system with respect to time, the influence from porosity of the formation were expressed under the influence of velocity of transport, but to an extend the transport progress to were the formation are subjected the microbial migration in the some strata

$$\frac{\partial v(x)}{\partial t} = \lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

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

Integrating the initial concentration for which $V_{(o)} = C_3$

$$SV_s - C_3 = \lambda^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

$$SV_s = \lambda^2 + C_3 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (25)$$

Making V_s the subject relation gives

$$V_s = \frac{\lambda^2 + C_3}{S} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (26)$$

Using Laplace inverse we obtain

$$V_t = \lambda^2 + C_3$$

$$\lambda^2 = \frac{Vt}{C_3} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (27)$$

If $\frac{VT^1}{T} = D_A v^2 \frac{x^1}{x} = -\frac{\partial v(x)}{\partial t} = \lambda^2 \ldots\ldots\ldots\ldots\ldots\ldots$ (28)

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

$$\frac{VT^1}{T} = D_A v^2 \frac{x^1}{x} - \frac{\partial v(x)}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (29)$$

Integrating both sides gives

$$\boxed{VC_1 \ell^{\frac{\lambda^2}{v}t} = D_A v^2 C_2 = \ell^{\frac{\lambda^2}{D_A v^2}t}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (30)$$

$$\boxed{C_{(x)} = VC_1 \ell^{\frac{\lambda^2}{v}t} = D_A v^2 C_2 \ell^{\frac{\lambda^2}{D_A v^2}t}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (31)$$

If $\lambda^2 = \frac{Vt}{C_3}$

We get

$$\boxed{C_{(x)} \quad VC_1 \ell^{\frac{\lambda^2 t}{v}} = D_A v^2 C_2 \ell^{\frac{vt^2}{C_2}t}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (32)$$

Three developed models from (30), (31) and (32) express their roles of the influential variables at various achievement, this is base on variation in behaviour in various formation at diverse depth, equation (30) express it model where by dispersion and velocities are dominant influences on the system, the concentration with respect to velocity and the rate of dispersion were more noticeable in equation (31), the parameters institute the rate of other variables through the rate of dispersion on velocity of flow. This stabilizes the structure; it displayed its purpose by ensuring that there is a relation between the concentrations from dispersion to the rate of velocity of the pollutants in another direction. This expression was under the influence of distance from where the pollutant are deposited. The expression in (31) maintained similar condition, but were established to relate the concentration with respect to distance, speedy movement of the microorganisms where establish to increase compared to the level of migration in (31), this implies that the movement has increase more, soil formation at this level deposit higher degree of void ratio and porosity thus producing more m increase in microbial population that determine the rate of concentration, the expressed model in (31) shows the rate degree of permeability of the soil, this determined the rate of velocity of flow that transport the contaminants, the concentration increase base on the rate of substrate deposition 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 condition also shows that increase in degree of permeability thus influence velocity of flow, this condition change the transport process of the microbes thus establishing mobile behaviour. Times and distance were found to sustain it rate base on the degree of porosity and velocity of transport. The developed model in equation (32) is the parameters that are influential in this phase, it express its vacillation from its progressive condition, the expressed model at this phase implies that the parameters coordinated them self together, by relating there functions, thus the behaviour of the microbes in terms of progressive condition, this depend on the deposition of the substrate in the formation, the behaviour of the microbe depend on this stated conditions.

$$C_{(x)} = T_{(x)} \; T_{(t)} \; X_{(t)}$$

$$C_{(x)} = VC_1 \, \ell^{\left(\frac{\lambda^2 t}{v}\right)\left(D_A v^2 C_2 \, \ell^{\frac{\lambda^2 t}{D_A v^2}}\right)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (33)$$

The movement of the microbes progressively changed their behaviour, this is based on the rate of several influential variables that may be allowable to them in mobile condition, but the study centered on the progressive stage of the microbial deposition in unconfined aquiferious zone, therefore the situation of its progressive condition implies that on the process of transportation, there is change in soil stratification thus permeability degrees influence the microbial migration to mobile state. Such state 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 progressive phase the microbes' are expected to increase under the influence of substrate deposition, the population may also reduce due to change in formation characteristics or inhibition deposition in the formation, So equation (33) microbes may maintained in there migration to ground water aquifers through change if the geological setting experiencing variation in flow.

Given the constraints below

Since $t = 0, \quad X = 0 = C_m$

$$C_m = C_1 \; C_2$$

Such that $C_1 = \frac{C_m}{C_2}$ .... (34)

$$C_{(x)} = \left(\frac{VC_m}{C_2} \ell^{\frac{\lambda t^2}{v}}\right)\left(D_A v^2 \ell^{\frac{\lambda^2 t}{D_A v^2}}\right) \qquad \ldots\ldots\ldots\ldots \qquad (35)$$

By indices, it simplifies ts

$$C_{(x)} = V^3 D_A C_m \ell^{\left(\frac{\lambda^2 t}{v} + \frac{\lambda^2 t}{D_A v^2}\right)} \qquad \ldots\ldots\ldots\ldots \qquad (36)$$

If $V = \frac{\partial}{t}$ we have

$$C_{(x)_t} = \frac{\partial^3}{t^3} D_A C_m \ell^{\left(\frac{\lambda^2 t}{\frac{d}{t}} + \frac{\lambda^2 t}{\frac{D_A d^3}{t^3}}\right)} \qquad \ldots\ldots\ldots\ldots \qquad (37)$$

$$C_{(x)_d} = \frac{\partial^3}{t^3} D_A C_m \ell^{\left(\frac{\lambda^2 t}{\frac{d}{t}} + \frac{\lambda^2 t}{\frac{D_A d^3}{t^2}}\right)} \qquad \ldots\ldots\ldots\ldots \qquad (38)$$

Or

$$C_{(x)_c} = \frac{\partial^3}{t^3} D_A C_m \ell \frac{\lambda^2 t^3}{d} + \frac{\lambda^2 t^3}{D_A d} \qquad \ldots\ldots\ldots \qquad (39)$$

The model in (39) is the final model equation, these express the progressive phase condition of microbial movement in soil and water environment, progressive phase condition were express mathematical to monitor Edwarosiella behaviour in mobile phase, the generated governing equation were derived in phases, this to descretized numerous significant parameters, so that there functions on the microbial behaviour will be express, the express equation generated lots of model considering several phase, thus the behaviour of the microbes in there movement process. The leading parameters that may develop mobile of the microbes were expressed in the system, the model express various condition base on the considered parameters that cause mobile state, this express there functions to the optimum level, the advantage of the model developed in phases were to understand several behaviour of the microbes under the influence of formation variable and its characteristics. This is to ensure that the conditions that cause mobile in microbial migration in the system process are determined, while migrating to ground water aquifers. This situation is to monitor the rate of transport that determined there functions, finally all the models were attached together to produces the final model equation that will monitor Edwarosiella in progressive phase condition in soil and water environment.

4. Conclusion

The formulated equation that govern the transport of Edwarosiella in unconfined aquifers has been mathematical evaluated, the governing equation were formulated by considering the parameters that are significant to microbial movement in progressive phase in soil and water environments, the developed equation were express in stages, the model were in phases in accordance with there behaviour, thus the variation of soil formation, the parameters that were significant in those state were considered, so that it will express its functions to the maximum on there migration to soil and water environment, this is to ensure that the behaviour of the microbes at each phase are full represented in the expressed model. The models were finally combined collectively to express the final model that will monitor the Edwarosiella phase in homogeneous unconfined aquifers.

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