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Research article

MODELING OF BATCH SYSTEM APPLICATION ON BACTERIOPHAGES TRANSPORT IN HOMOGENEOUS COARSE AQUIFER INFLUENCED BY PERMEABILITY IN ELELE, RIVERS STATE OF NIGERIA

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Abstract

Modeling of batch system in Bacteriophage transport in homogenous coarse soil influenced by permeability has been developed. The models were necessary because the contaminants were found to generate high concentration in ground water aquifer. Public health was deteriorating in the study area and the source of pollution was ignored due to lack of information. To solve the problem, mathematical models were developed to monitor the transport of these contaminants in a homogeneous formation, application of batch systems were applied due to uniformity of the formations in the study area. This conceptual framework was in line with the stratification of the soil, including the degree of predominant homogeneous deposition at shallow aquifers. The model was confirmed suitable to solve the pollution transport in the study location.

Keywords: modeling batch system, coarse sand, and permeability.

1. Introduction

The incident and movement of human enteric viruses and microbes in and through groundwater have been an old public concern. Questions of virus transport are central to groundwater wellhead guard. Distances between virus sources such as septic tanks and drinking water wells are characteristically set on the basis of empirical relations. Quantitative estimates based on site-specific characteristics or transport modeling has not been used for setting groundwater guard standards. bodily and mathematical models for describing the fate of biocolloids (i.e., virus and bacteria) in porous media have been suggested for more than a decade [e.g., *Vilker*, 1978; *Vilker and Burge*, 1980; *Funderburg et al*., 1981; *Grosser*, 1985; *Corapcioglu and Haridas*, 1984, 1985; *Yates et al*., 1987; *Matthess et al*., 1988; *Harvey and Garabedian*, 1991]. Though, application of these models has suffered in part from a lack of methodical field and laboratory research. Accumulations of experimental data and Validations of existing or newly developed models with data are necessary.

The main factors controlling virus and microorganisms fate in subsurface porous media are attachment to and detachment from the porous medium surfaces, growth and inactivation, and advection and spreading [*Bales et al*., 1991; *Gerba et al*., 1991; *Harvey*, 1991]. Advection depends on groundwater speed. Spreading depends on velocity and aquifer heterogeneity and is scale reliant. Attachment and detachment rates are sensitive to groundwater chemical circumstances, such as *p*H, ionic strength, and the composition of the porous media [*Gerba*, 1984; *Bales et al*., 1993], and in numerous cases are the most significant factors controlling microbes and virus migration. Inactivation of viruses depends strongly on temperature [*Yates et al*., 1987] and is characteristically sluggish compared to the rates of advection, attachment, and detachment [*Bales et al*., 1995]. precise forecast of virus transport through porous media near their source therefore frequently depends exclusively on the correct assessment of the rates at which viruses attach to or detach from the porous medium surfaces Bacteriophages (phages) are viruses which infect bacteria. They were discovered independently by Frederick W Twort in England in 1915 and by Felix d'Herelle at the Pasteur Institute in Paris in 1917 (Pelczar et al., 1988 Melissa and Charles, 1997). Phages were the last of the three major classes of viruses to be discovered during World War I. The other two classes were the plant viruses and animal viruses. It was then hoped that their ability to kill bacteria could be used for the prevention and treatment of bacterial disease, but this did not prove successful due to the rapid selection of resistant bacteria (Goyal et al., 1987 Wok 2000). However, phages eventually turned out to have major other benefits, notably as models or surrogates for human viruses in basic genetic research as well as water quality assessment. Phages proved to be most valuable tools in research on viruses because compared with the human, animal, plant and even insect hosts of other viruses, phages are easily and rapidly cultivated in laboratories which are not particularly demanding with regard to space, facilities, and equipment (Pelczar et al., 1988). Research on the basic genetic properties of phages led to the development of an entirely new science - that of molecular biology - which allowed unprecedented advancements in all the biological and medical sciences. In addition, the way all viruses reproduce was first indicated by work with phages (Ackermann, 1969). Aquifer passage reduces pathogenic microorganism concentrations, and abundant successes have been reported in cases, like artificial recharge schemes or riverbank filtration projects, where microorganisms were completely removed. However, studies in the USA have shown that up to half of all US drinking water wells tested had evidence of fecal contamination and an estimated 750,000 to 5.9million illnesses and 1400-9400 deaths per year may result from infected groundwaters (Macler and Merkle, 2000). Figures on illnesses and deaths as a result from contaminated groundwater for the developing world are not accessible. However, in Africa around 80% of the population in the largest cities (in Asia: around 55%) have on-site hygiene, such as septic tanks, pour-flush, VIP latrines or simple pits (World Health Organization, 2000-2003), and, according to Foster (2000), in developing countries in Asia, South America and Africa for an estimated1,300 million persons living in urban areas, the main source of drinking water. .Groundwater may be impure, when wastewater infiltrates into the soil and recharges groundwater via leaking sewerage systems, leakage from manure, wastewater or sewage sludge spread by farmers on fields, waste from animal feedlots, waste from healthcare facilities, leakage from waste disposal sites and landfills, or artificial recharge of treated waste water. If the distance from source of pollution to point of abstraction is small, there is a real chance of abstracting pathogens. To predict the presence of pathogens in water, usually a separate group of microorganisms is used. The common descriptive term for this group of organisms is fecal indicator organisms (Medema et al., 2003), from which *Escherichia coli* (or *E. coli*) and Thermotolerant coliform bacteria are two important members. *E. coli* is widely preferred and used as an index of fecal contamination (World Health Organization, 2003; Jan 2007), because its detection is relatively simple, fast and reliable, and the organism is routinely measured in water samples throughout the world. The same applies to Thermotolerant ('fecal') coliforms. These coliform sare a less reliable index of fecal contamination than *E. coli*, although under most circumstances their concentrations are directly related to *E. coli* concentrations (World Health Organization, 2003).

2. Theoretical Background

The rate of Bacteriophages deposition in unconfined bed has been an issue of environmental concern to experts. Regeneration of contaminants is ignored due to lack of information on the source of the solute deposition in phreatic aquifers. Elele, Rivers State of Nigeria geological setting is from the deposition of deltaic stratification, the formation in deltaic environment from hydrogeological studies deposit unconfined aquifer where the rate of permeability are very high in the study area. This formation express a lot of influence from formation characteristics, but the focus of the study is on permeability of the soil as the source of fast migration of Bacteriophages in the study area. Stratification of the soil are prone to fast migration of contaminants, this has resulted to lots of water pollution, and most illnesses found in those areas are from water pollution through the deposition of Bacteriophages in the study area.

Most sources of the Bacteriophage are from manmade activities, generating from a lot of indiscriminate dumping of the waste without thorough treatment. To solve the problem, mathematical equations were developed, this source of pollution from groundwater were formulated using mathematical tools, necessary variables that influence the transport of these microbes were considered as parameters in the system, these produced the governing equation in homogenous coarse sand, the models are expressed below.

$$K\, C_{(x)} \frac{\partial V_{(x)}}{\partial t} = V \frac{\partial C_{(x)}}{\partial t} \qquad \text{.......................................} \qquad (1)$$

Equation (1) is the governing equation developed to determine the rate of Bacteriophages migration in homogeneous coarse sand. The expressions show the parameters that influence the transport system in unconfined bed. Since the formation is in uniform soil, batch systems application were found suitable in developing the governing equation, the concentration in the system are with respect to time.

$$\frac{\partial V_{(x)}}{\partial t} = K C_{(x)} \frac{\partial V_{(x)}}{\partial t} \qquad \text{(2)}$$

$$\frac{V \partial C_{(x)}}{\partial t} = K C_{(x)} \frac{V_{(x)}}{t} \qquad \text{(3)}$$

$$V/V_x \frac{\partial C_{(x)}}{\partial (x)} = -\frac{K dt}{t} \qquad \text{(4)}$$

$$V/V = \int 1/C_{(x)} \; \partial C_{(x)} = -K \int \frac{\partial t}{t} \qquad \text{(5)}$$

$$V/V_{(x)} \left[\ln C_{(x)} = -K \ln \frac{t_o}{t} \right] \qquad \text{(6)}$$

$$\ln \frac{C_{(x)}}{C_{(x)o}} = -K \frac{V_{(x)}}{V} \ln \frac{t}{t_o} = \ln\left(\frac{t}{t_o}\right) - K \frac{V_x}{V} \qquad \text{(7)}$$

$$\frac{C_{(x)}}{C_{(x)_o}} = \left(\frac{t}{t_o}\right) - \frac{K V_x}{V} \qquad \text{(8)}$$

$$\frac{C_{(x)}}{C_{(x)_o}} = \ell^{-K \ln\left(t/t_o \right) V_x/V} \qquad \text{(9)}$$

$$C_{(x)} = C_{(x)_o} \ell^{-K \ln 1/t \; V_x/V} \qquad \text{(10)}$$

$$C_{(x)} = \beta \ell^{-K \ln 1/t} \; Vx/V \qquad \text{(11)}$$

$$\boxed{\beta = C_{(x)_o} \ell \frac{V_{(x)}}{tv}} \qquad \text{(12}$$

The expressions in equation (12) were the derived models; the initial concentrations at stage were expressed. This implies that at the point of discharge, the velocities play major roles under exponential phase base on the regeneration of these contaminants. It means constant high deposition of at the point of discharge in soil formation. Organic soil is the victim of these contaminants, this is under the influence of time of deposition and transport, but for batch application, uniform soil on transport process are monitored, time of concentration determined very fast migration of microbes in the study area. .

Therefore, the expression in (12) monitor the initial concentration that should the point of discharge, monitoring microbial transport in coarse sand implies that the formation may develop constant velocity and flow in the formation, but in most cases the microbial migration may experience inhibition due to the deposition of microelements, therefore the model at equation (12) will be integrated with other parameters that will be considered in the transportation system.

Model develop at this phase will be used to determine the rate of Bacteriophages Transport influenced by permeability.

The equation were expressed integrating the influence parameter permeability (K) as

$$C_{(x)} = \beta \ell^{-KVt} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (13)$$

Permeability was integrated in the system, because the formation must be permeable, if the solute must migrate fast, the permeability of the soil was integrated in the model expression. In (13) the expression was transformed to express the function of permeability (k) as a subject that has a serious role in the transport of the solute.

Take Laplace Transform of (13) we have

$$C_{(o)} = \frac{\beta}{KV + S} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (14)$$

i.e. $C_{(o)}\left[KV + S\right] = \beta$

$$\Rightarrow \quad C_{(o)} KV + C_{(o)} S - \beta = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (15)$$

By applying quadratic formula in (15), we have

$$C_{(x)} = \frac{-S \pm \sqrt{S^2 + 4\beta KV}}{2KV} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (16)$$

Our equation (15) can be expressed as follows if our $S = KV$

$$i.e. \quad C_{(x)} = -KV \pm \frac{\sqrt{K^2V^2 + 4\beta KV}}{2KV} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (17)$$

Now the general solution of (16) is

$$C_{(x)} = A\ell^{\left[-KV\sqrt{-K^2V^2 + 4\beta KV}\right]t} + \beta\ell^{\left[-KV - \sqrt{K^2V^2 + 4\beta KV}\right]t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (18)$$

Further application were done, where quadratic formula were introduced to discretize the parameters in terms of expressing there roles in the system together, the parameters were denoted with quadratic symbols and were applied form equation (16) to (18), the expression generated microbes on exponential phase since the formations are homogenous and at this point the deposition of microelement are assumed to deposit at this formation, it means that degree permeability of coarse sand will be very high, so the expression in equation (18) shows the exponential phase of the microbes in homogenous coarse sand under the influences of permeability .

At initial point, $x = 0, t= 0$ and $C(o) = 0$

So that our (16) can give the constant A and β, values of 1 and -1. A = 1 and $\beta = -1$

So that equation (16) can be expressed as

$$C_{(x)} = \ell^{\left[-KV+\sqrt{K^2V^2+4\beta KV}\right]t} - \ell^{\left[-KV-\sqrt{K^2V^2+4\beta KV}\right]t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

Again $\ell^x - \ell^{-x} = Sin\, x$, now our equation (19) cam ne rewritten in this form

$$\boxed{C_{(x)} = 2Sin\left[KV+\frac{\sqrt{K^2V^2+4\beta KV}}{2K}\right]t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

Subject to the transport condition, boundary values were expressed, to determine the limit of transport and concentration in the system. the Limits determine the level of migration in soil under the influences of soil and water environment. Microbes increase in microbial population and decrease due to environmental condition. Thus degradation of substrate and temperature in the soil are experienced in the transport process, these is through concentration with respect to time under the influence of stratification variation in the formations. This condition implies that the microbes cannot be in exponential state at every condition, the expression developed to were suncidal formular were integrated in the derived mathematical expression, so equation (19) where expression by rearranging the equation into suncidal expression generated the final model at (20).

The expression at (20) is the final model that will monitor the rate of Bacteriophages migration in homogeneous formation, under the influence of permeability. The study area is deltaic in nature, the formations are prone to fast migration of any contaminant but vary due to slight variation in few area as expressed in hydrogeological studies. The developed models are expressed basically on concentration with respect to change in time under the influence of homogeneous formation and permeability of the stratum. The models were developed based on the considered parameters for homogeneous coarse sand in the study area.

3. Conclusion

The rate of Bacteriophages deposition in the study area cannot be overemphasized, the rate of concentration in the study area, were considered through the rate of permeability in the formation, other influence from the deltaic environment were considered in the system that produced the governing equation, the expressed equation determine the migration of the microbes in a uniform formation. The systems were considered as batch since the formation were homogenous, the expressed governing equation were developed based on the condition of the formation, the mathematical expression were derived to generate the model, the equations were derived considering some influential parameters that influence the migration of the microbes in such condition. The equation finally generated the model that will monitor the transport of Bacteriophages in the homogeneous coarse soil. The study is imperative because the deposition of Bacteriophages in the homogeneous coarse formation will help experts to manage groundwater system and prevent several illness of generated from these type of microbial concentration in the study area.

References

[1] Ackermann H W (1969) Bacteriophages proprieteset premieres etapesd'une classification. *Path-Biol*. **17** 1003-1024.

[2] Goyal SM, G CP and Bitton G (1987) *Phage Ecology*. John Wiley and Sons, New York. 321 pp

[3] Pelczar M J (Jr), Chan ecs and Krieg NR (1988) *Microbiology* (5th edn.) McGraw-Hill Book Co, Singapore. 416 pp.4

[4] Bales, R. C., S. R. Hinkle, T. W. Kroeger, K. Stocking, and C. P.Gerba, 1991 Bacteriophage adsorption during transport through porousmedia: chemical perturbations and reversibility, *Environ. Sci. Technol*.,*25*, 2088–2095,.

[5] Bales, R. C., S. Li, K. Maguire, M. Yahiya, and C. P. Gerba, 1993.MS-2phage and poliovirus transport through porous media: sorbent hydrophobicityand chemical perturbations, *Water Resour. Res*., *29*,957–963,

[6] Gerba, C. P., Applied and theoretical aspects of virus adsorption to surfaces, *Adv. Appl. Microbiol*., *30*, 133–168, 1984.

[7] Gerba, C. P., M. V. Yates, and S. R. Yates, 1991 Quantization of factors controlling viral and bacterial transport in the subsurface, in *Modeling the Environmental Fate of Microorganisms*, edited by C. J. Hurst, pp. 77–88, Am. Soc. for Microbiol., Washington, D. C.,

[8] Harvey, R. W., and S. P. Garabedian, Use of colloid filtration theory in modeling movement of bacteria through a contaminated sandy aquifer, *Environ. Sci. Technol*., *25*, 178–185, 1991

[9] Yates, M. V., S. R. Yates, J. Wagner, and C. P. Gerba, Modeling virus survival and transport in the subsurface, *J. Contam. Hydrol*.,*1*, 329–345, 1987

[10] Foster, S.S.D., 2000. Groundwater resources at the turn of the millennium: taking stock and looking forward. In: *Groundwater: past achievements and future challenges, Sillo et al. (eds.),*
Balkema, Rotterdam, The Netherlands, ISBN 90 5809 159 7

[11] Harvey, R. W., and S. P. Garabedian, Use of colloid filtration theory in modeling movement of bacteria through a contaminated sandy aquifer, *Environ. Sci. Technol*., *25*, 178–185, 1991.

[12] Medema, G.J., P. Payment, A. Dufour, W. Robertson, M. Waite, P. Hunter, R. Kirby and Y. Andersson, 2003. Safe drinking water: an ongoing challenge. In: *Assessing microbial safety of drinking water: improving approaches and methods, Dufour et al. (eds.).* World Health Organization, 2003.ISBN 92 4 154630.

[13] Macler, B.A. and J.C. Merkle, 2000. Current knowledge on groundwater microbial pathogens and their control.Hydrogeol. J. (2000), vol. 8, no. 1, pp. 29-40

[14] World Health Organization, 2000-2003. Global Water Supply and Sanitation Assessment 2000 Report.http://www.who.int/docstore/water_sanitation_health/globassessment

[15] Funderburg, S. W., B. E. Moore, B. P. Sagik, and C. A. Sorber, 1981 Viral transport through soil columns under conditions of saturated flow, *Water Res*., *15*, 703–711,

[16] Vilker, V. L., and W. D. Burge, 1980. Adsorption mass transfer model for virus transport in soils, *Water Res*., *14*, 783–790,.

[17] Vilker, V. L., and W. D. Burge, 1980 Adsorption mass transfer model for virus transport in soils, *Water Res*., *14*, 783–790,

[18] Corapcioglu, M. Y., and A. Haridas1984 Transport and fate of microorganisms in porous media: a theoretical investigation, *J. Hydrol*., *72*, 149–169, .

[19] Corapcioglu, M. Y., and A. 1985 , Microbial transport in soils and groundwater: A numerical model, *Adv. Water Resour*., *8*, 188–200,

[20] Matthes, G., A. Pekdeger, and J. Schroeter, 1988.Persistence and transport of bacteria and viruses in groundwater—a conceptual evaluation, *J. Comtam. Hydrol*.,*2*, 171–188,.

[21] Yates, M. V., S. R. Yates, J. Wagner, and C. P. Gerba, Modeling virus survival and transport in the subsurface, *J. Contam. Hydrol*.,*1*, 329– 345, 1987

[22] Roger C. Bales, Shimin Li,1 and T.-C. Jim Yeh 1997 Bacteriophage and microsphere transport in saturated porous media: Forced-gradient experiment at Borden, Ontario water resources research, vol. 33, no. 4, pages 639–648, april

[23] Jan Willem Anton Fop pen 2007 Transport of *Escherichia coli* in saturated porous Published by A.A. Balkema Publishers, a member of Taylor & Francis Group plc. www.balkema.nl and www.tandf.co.uk Taylor & Francis Group plc, London, UK

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