World Journal of Science and Technology Research
Vol. 1, No. 9, December 2013, PP: 235- 245, ISSN: 2329 - 3837 (Online)
Available online at www.wjst.org

Research article

MODELING DECAY PHASE CONDITION OF THERMOTOLERANT DEPOSITION IN SILTY AND FINE SAND FORMATION AT COASTAL AREA OF TRANS-AMADI, PORT HARCOURT

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@hotminthe srail.com
E-mail: solomoneluozo2000@yahoo.com

Abstract

Modeling the state of decay phase of thermotolerant in silty and fine sand formation has been thoroughly evaluated, the behaviour of the microbes were observed in previous investigation that determine the fluctuation level of the contaminant at different formation. The investigation could not generate thorough solution that will prevent or engineer out this contaminant in the study location, modeling the deposition and transport of thermotolerant were find appropriates due to inefficiency of the previous results, the model were derived from the governing equation generated from the system formulated, the rate of thermotolerant deposition are through high degree of soil permeability and porosity, such soil structural influences were observed to pressure the transport of the microbes, but in the transport process in some region of the formation developed other influence that may cause the microbes to degrade in microbial population, this is observed in some condition of thermotolerant in some region of the formation, such condition, the microbes developed fluctuation in microbial population, the expressed model examined these condition in developing the derived model to monitor this behaviour of thermotolerant in the study environment.

Keywords: modeling decay phase, thermotolerant deposition, silty and fine sand formation

1. Introduction

Potentially harmful microbes may enter ground water via poor well construction, ground water recharge/infiltration from the surface, faulty septic tanks and/or sewer lines, land application of sewage sludge, and percolation of landfill leachate (Sobsey 1979; Pedley and Howard 1997). The fate of microorganisms in the subsurface depends on two basic processes, survival and transport/retention (Gerba and Bitton 1984; David, 2003). Study of the transport of microorganisms to and through ground water is an entire field onto itself. Considerable work has been done to define factors affecting microbial transport in ground water, generally with two motivating reasons: public health implications from contamination by potential pathogens, and transport of biodegrading bacteria to aquifer regions contaminated with chemical constituents. Transport studies often involve the use of columns to model movement through a soil matrix or *in-situ* studies of microbial transports which employ monitoring wells to detect the organisms of interest, often a tracer organism, as they are transported with ground water across a study site. Column studies are useful for isolating and/or defining specific impacts controlling transport as they offer a controlled environment, while *in-situ* studies allow for evaluating the impact of other factors in the natural environment that are difficult or impossible to model with column studies. Such factors could include predation and antagonism by other organisms, alterations in adsorption and survival in response to natural geochemical constituents and pore size or transmissivity effects of the undisturbed aquifer material, and interrelation of these and other variables (Harvey 1997, David, 2003). Also, many physical parameters of water and contaminant transport, such as dispersion, have scale dependency, and thus *in-situ* studies more accurately model these parameters.

Numerous factors have been identified which impact transport of bacteria and/or viruses in ground water. Beyond the bulk flow of water in an aquifer or soil (advection), physical and chemical parameters of the solid matrix, the ground water, and the organisms affect the degree to which microbial particles are retained or transported and the relative rates at which they might move compared to the water itself. The primary mechanisms of retention in soil and aquifers are thought to be adsorption for viruses and size dependent straining for bacterial and protozoan cells, although bacteria and to a lesser degree protozoa are also retained by adsorption (Gerba and Bitton 1984; Newby 2000, David, 2003). Electrostatic adsorption is one mechanism of retention. A major force governing adsorption is the electrostatic interaction between microbial particles and solid surfaces. This force is generally repulsive since microbes and soil surfaces generally have net negative charges. Two major determinants of surface charge on organisms are the isoelectric point of the cell/virion and pH of the water. By and large, microbial cells/particles have a negative surface charge in near-neutral water (Gerba 1984; Klein and Ziehr 1990; Krekeler 1991). But the overall charge on an organism is highly variable. Isoelectric point (pI) is the pH at which the surface groups on a particle are neutralized via the bonding of an H+ ion at a negative site or loss of H+ from a positively charged site such as -OH2 + or phosphate groups (Gerba 1984). While positive and negative charges may remain on the surface, the net charge is zero. Thus, organisms in water of pH below their pI will be neutral to positively charged. The isoelectric point of viruses varies among types and strains, and these variations are a major control on adsorption, such that adsorption is negatively correlated to is electric point (Dowd 1998). This effect also varies with soil and water chemistry, such that water of neutral or higher pH facilitates adsorption, as does greater ionic strength (I) of the water and the abundance of trivalent or divalent cations such as aluminium and calcium on soil particles (Fontes 1991; Newby

2000). Adsorption will occur when the electrostatic repulsion is diminished enough for attractive forces to overcome it; attractive forces are a combination of van der Waals forces and hydrophobic interactions. Hydrophobicity of a microbial cell/particle also plays a role in its adhesion to surfaces. Generally, virus particles and bacteria have lipid side chains or lipid coats, as well as portions of surface proteins that will be hydrophobic. Usually, proteins fold in such a way that hydrophilic amino acid regions are exposed, but some hydrophobic regions will be exposed nonetheless and these may play a role in hydrophobic interactions (Gerba 1984; Newby 2000). Thus, organic content of the soil and ground water also affect adsorption. While higher organic content of soil can facilitate binding of more hydrophobic organisms (Newby 2000), greater dissolved organic matter can enhance transport by blocking hydrophobic binding sites or reduce adsorption of non-hydrophobic organisms such as the coliphage MS-2 (Powelson 1991 David, 2003). The water content of soil plays a large role in microbial transport. Comparisons of retention of viruses have revealed that removal is greater through unsaturated vs. saturated ground water flow (Powelson 1990; Jin 2000). This is largely because of closer proximity of microbial particles to soil particle surfaces and possibly more rapid inactivation under unsaturated conditions. Physical components of the soil or aquifer material such as grain size and other size-dependent exclusion factors such as cell size have a role in controlling transport via straining (Gerba and Bitton 1984; Fontes 1991; Harvey 1997). Other hydrological factors are also important such as advective flow velocity and the heterogeneity of the aquifer system (Harvey 1997). Transport studies are often used to define modeling equation components, which can then be useful for predicting transport rates and distances through a particular aquifer based on the values of various parameters (Yates and Yates 1988; Sinton 2000).

2. Theoretical background

The study of decay phase condition has been previous expressed in different way by some other experts around the globe; the behaviour of decay phase condition of thermotolerant might not be the same with other microbial species, the behaviour of this type of microbial species were found to have developed fluctuating results from investigations carried out thus the analysis shows how the deposition of the microbes varies in population size in the study environment. Such condition have been caused by several formation characteristics and other deposited minerals in the soil formation, There are a number of situations where it may not be possible to quantify the concentration of substrate-degrading organisms in a heterogeneous microbial community. However, the rate of substrate depletion can be measured. There are also situations in which the organism concentration remains essentially constant even as the substrate is degraded (i.e. no growth situation). Given these various features of biodegradation kinetics, different models including first-order, zero-order, logistic, Monod (with and without growth) and logarithmic models can be used to describe biodegradation. Biodegradation kinetics is used to predict concentrations of chemical substances remaining at a given time during *ex situ* and *in situ* bioremediation processes. In most cases, information is based on loss of parent molecule targeted in the process. The key interest is frequently the decrease in toxicity concentration. Nevertheless, toxicity measurements require bioassays, which are always very difficult and tedious. Therefore, efficacy of biodegradation is based on chemical measurements, e.g. disappearance of parent molecule appearance of

mineralization products or disappearance of other compounds used stoichiometrically during biodegradation of a compound, for instance, electron acceptors. There are several scenarios by which a compound can be transformed biologically. Okpokwasili and Nweke, 2005. Progress in modelling microbial processes in porous media is essential to improving our understanding of how physical, chemical, and biological processes are coupled in groundwater and their effect on groundwater- chemistry evolution, bioremediation, and the reactive transport of contaminants and bacteria. Much of the emphasis to date has been on quantitative representations of either the kinetics of contaminant degradation or the physical (or physicochemical) processes that affect the transport of bacteria in porous media, primarily because these issues are more tractable to the microbiological and hydrologic transport fields. Whether the modelling objective is to understand the biodegradation of contaminants or the movement of bacteria, the processes that must be considered are the same. These processes are generally divided into physicochemical and biological. The physicochemical processes include advection, diffusion, dispersion, exclusion, straining, and physical filtration. The physicochemical processes are primarily based on the structure and properties of the groundwater flow system and porous media. Consequently, most reactive transport models incorporate some of the major physical processes, and these processes have been the focus of numerous experimental and numerical modelling studies on colloid and biocolloid research. In contrast, the biological processes of growth/decay, chemotaxis, predation, physiological adaptation (survival), and

adhesion or active detachment are characteristics of the bacterial population and by comparison have received little attention in field-scale hydrogeologic transport models. Although many researchers readily acknowledge the importance of growth processes in transport (Harvey et al. 1984; Hornberger et al. 1992 Ellyn and Timothy 2000).

3. Governing Equation

$$K\phi\frac{\partial^2 c_{(x)}}{\partial t^2} = KV_{(x)}\frac{\partial c}{\partial x} + KD\frac{\partial c}{\partial x} \qquad \text{…….. (1)}$$

The expression in [1] is the principal equations in the study location, the behaviour of the thermotolerant deposition in the formation are replicated on the soil structures deposited that pressure the deposition of thermotolerant in study location. Permeability play major role in the rate of movement of the microorganisms to some area were change in strata deposition may developed adverse condition for the microbes if it cannot adapt, it will move or degrade by reducing it microbial inhabitants.

$$\left.\begin{aligned} t &= 0 \\ x &= 0 \\ C_{(o)} &= C_o \\ \frac{dc}{dt}\Big|_{t=0} &= 0 \end{aligned}\right\} \qquad \text{…….. (2)}$$

$$K\phi\frac{\partial^2 c}{\partial t^2} = -KD\frac{\partial c}{\partial x} \qquad \text{…….. (3)}$$

$$\left.\begin{array}{l} t \;\; = \; 0 \\ x \;\; = \; 0 \\ C_{(o)} \; = \; C_o \\ \dfrac{dc}{dt} \end{array}\right\} \qquad \text{…………………………..} \; (4)$$

$$KV_{(x)} \frac{\partial c}{\partial x} + KD \frac{\partial c}{\partial x} \qquad \text{…………………………..} \; (5)$$

$$\left.\begin{array}{l} x \;\; = \; 0 \\ C_o \;\; = \; C_o \\ \left.\dfrac{dc}{dx}\right|_{x \,=\, 0} = \; 0 \end{array}\right\} \qquad \text{…………………………..} \; (6)$$

Apply direct integration on (1)

$$K\phi \frac{\partial c}{\partial t} \; = \; K\phi s \; + K_1 \qquad \text{…………………………..} \; (7)$$

Again, integrate equation (7) directly, it yields

$$K\phi s + K\phi s \; + K_1 \; + K_2 \qquad \text{…………………………..} \; (8)$$

Subject to equation (2), we have

$$K\phi s \; C_o \; = \; K_2 \qquad \text{…………………………..} \; (9)$$

and subjecting equation (7) to (2)

at $\left.\dfrac{dc}{dt}\right|_{t \,=\, 0} = \; 0 \quad C_{(o)} \; = \; C_o$

Yield

$$0 \; = K\phi s \; C_o + K_2 \qquad \text{…………………………..} \; (10)$$

So that we put (9) and (10) into (8), we have

$$K\phi s = C_o \, Cst \; - \; C_o \, Cst \; + K\phi \qquad \text{…………………………..} \; (11)$$

$$K\phi C_o = Cs C_o t \; = \; K\phi C_o - \; Cs C_o t \qquad \text{…………………………..} \; (12)$$

$$\Rightarrow C_o, \left(K\phi - Cst\right) = \; C_o \; \left(K\phi - Cst\right)$$

$$\Rightarrow C_o = C_o \qquad \text{.............................. (12)}$$

Hence equation (13) entails that at any given distance *x*, we have constant concentration of the contaminant in the system.

$$K\phi \frac{\partial c}{\partial t} = -KD\frac{\partial c}{\partial x} \qquad \text{............. (3)}$$

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

$$C_o = ZT \qquad \text{.............................. (14)}$$

$$\text{i.e. } \frac{\partial^2 c}{\partial x^2} = XT^{11} \qquad \text{.............................. (15)}$$

$$\frac{\partial^2 c}{\partial x} = X^1 T \qquad \text{.............................. (16)}$$

Put (15) and (16) into (14), so that we have

$$K\phi XT^{11} = KD\, X^1 T \qquad \text{.............................. (17)}$$

$$\text{i.e. } K\phi \frac{T^{11}}{T} = KD\frac{X^1}{X} = -\lambda^2 \qquad \text{.............................. (18)}$$

Hence

$$K\phi \frac{T^1}{T} = \lambda^2 X = 0 \qquad \text{.............................. (19)}$$

$$\text{i.e. } X^1 + \lambda^2 X = 0 \qquad \text{.............................. (20)}$$

And

$$KDX^1 + \lambda^2 X = 0 \qquad \text{.............................. (21)}$$

$$\text{From (20) } T = A Cos \frac{\lambda}{\sqrt{K\phi}} t + B\, Sin \frac{\lambda}{\sqrt{KD}} x \qquad \text{.............................. (22)}$$

And (15) give

$$X = C_o \, \ell^{\frac{-\lambda^2}{\sqrt{KD}} x} \qquad \text{.............................. (23)}$$

By substituting (22) and (23) into (14) we get

$$Co_2 = \left(ACos \frac{\lambda}{\sqrt{K\phi}} t + B Sin \frac{\lambda}{\sqrt{KD}} t \right) Co\, \ell^{\frac{-\lambda}{\sqrt{KD}} x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

Progressive stage of microorganism were considered the derived solution, deriving the principal equation, the progressive phase of the transport process were considered, this implies that the migration process should be monitored to the point where change in formation may developed unfaviourable condition for the microbes, dilapidation process begin to take place, whereby on decay condition degradation influenced by other deposited variables, the population of the microbes in such condition are considered. The developed model at [24] were establish to contain the condition of rapid transport to where change in soil structural deposition influenced by other minerals will cause decomposition on the microbes.

Subject to equation (24) to condition in (4), so that we have

$$C_o = AC \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (25)$$

$\therefore$ Equation (25) becomes

$$Co_2 = Co\, \ell^{\frac{-\lambda^2}{\sqrt{KD}} x} Cos \frac{\lambda}{\sqrt{K\phi}} t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (26)$$

Again

$$\left. \frac{dc_2}{dt} \right| \begin{matrix} = 0 \\ t = 0, B \end{matrix} x = 0$$

Equation (26) becomes

$$\frac{dc_2}{dt} = \frac{\lambda}{\sqrt{K\phi}} \ell^{\frac{-\lambda^2}{\sqrt{KD}} x} Sin \frac{\lambda}{\sqrt{K\phi}} t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (27)$$

i.e. $0 = Sin \frac{\lambda}{\sqrt{K\phi}} 0$

$\frac{C_o \lambda}{\sqrt{K\phi}} \neq 0$ Considering NKP

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

$$0 = \frac{-C_o \lambda}{\sqrt{K\phi}} Sin \frac{\lambda}{\sqrt{K\phi}} B \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (28)$$

$$\Rightarrow \frac{\lambda}{\sqrt{K}} = \frac{n\pi}{2} n = 1, 2, 3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (29)$$

$$\Rightarrow \quad \lambda = \frac{n\pi\sqrt{K\phi}}{2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

So that equation (26) becomes

$$Co_2 = Co\,\ell^{\frac{-n^2\pi^2K\phi}{2KD}x}\, Cos\,\frac{n\pi}{2}\frac{\sqrt{KD}}{2\sqrt{KD}}t \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (31)$$

$$Co = Co\,\ell^{\frac{-n^2\pi^2K\phi}{2KD}x}\, Cos\,\frac{n\pi}{2}t \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (32)$$

Micronutrient are one of the source of energy found in some region of the formation, by experiencing increase of microbial population in soil the study environment, the examination of the work has pressure on the behaviour of the microorganisms when it migrate to some region of the formation it will experiences discomfort, it will try to establish adaptation, but for any reason it they could not adapt, they will travel to where it will favuorable for them, in such circumstance there is the tendency that they will travel to another structure of the soil where there is substrate deposition, therefore regeneration of thermotolerant will occur and it activities continue and increase microbial population as it was observed. The establish model in [32] will be useful to monitor the deposition of the microbes in such exponential phase.

Now we consider equation (5) which is the steady flow state of the system

$$KV_{(x)}\frac{\partial c}{\partial x} - KD\frac{\partial c}{\partial x} \qquad \ldots\ldots\ldots \quad (5)$$

Using Bernoulli's method, we have

$$C_3 = XT \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (33)$$

$$\frac{\partial c_3}{\partial t} = X^1T \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (34)$$

$$\frac{\partial c_3}{\partial t} = X^1T \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (35)$$

Put (34) and (35) into (5), so that we have

$$KV_{(x)}X^1T = -KDX^1T \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (36)$$

i.e. $$KV_{(x)}\frac{X^1}{X} = -KD\frac{X^1}{X} \quad \varphi \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (37)$$

$$KV_{(x)}\frac{X^1}{X} = \varphi \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (38)$$

$$-KD\frac{X^{1}}{X} = \varphi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (39)$$

i.e. $X = A\ell^{\frac{\varphi}{KV_{(x)}}x}$ …….. (40)

And $X = B\ell^{\frac{\varphi}{KD}x}$ …….. (41)

Put (40) and (41) into (33), gives

$$C_3 = A\ell^{\frac{\varphi}{KD}x} \bullet B\ell^{\frac{-\varphi}{KD}x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (42)$$

The transport process of microorganisms are establish to experiences stead state flow, even when they observed reduction in microbial population in the migration state, such situation has been noted in the structure, this may take places when the transport process is on the motion to the point where formation influences may pressure them to station at some particular area of the formation. Such condition were considered in the system and therefore the derived expression developed this model at [42] to monitor the system in the trend

Subject equation (40) to (6) yield

$$C_3 = (o) = C_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (43)$$

So that equation (44) becomes

$$C_3 = C_o\ell^{(x-y)\frac{\varphi}{KD}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (44)$$

Now assuming that at the steady flow, there is NKP for substrate utilization, our concentration here is zero, so that equation (46) becomes

$$C_3 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (45)$$

Therefore, solution of the system is of the form

$$C_o = C_1 + C_2 + C_3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (46)$$

We now substitute (13, (32) and (46) into (47), so that we have the model of the form

$$C_o = C_o + Co\ell^{\frac{-n^2\pi^2K\phi}{KD}t} Cos\frac{n\pi}{2}x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (47)$$

$$C_o = C_o\left(1+\ell^{\frac{-n^2\pi^2K\phi}{2KD}t} Cos\frac{n\pi}{2}x\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (48)$$

The developed model in [48] are an expression from the derived governing equation, the final equation is the rundown of all the model at various measured condition, the derived solution were integrated to generate the final model that will examine the decay phase of thermotolerant in the study environment. Predominant formation

characteristics such as porosity and permeability deposition were found to influences the system, while on the process it is observed how degradation in some region of formation was established, such circumstance considered these behaviour under the influences of formation characteristics in the study area, this were experienced in most situation on transport process of such the types microbial specie in the study location, the final model will definitely express this condition to ensure that the final model monitor the microbes in decay stage condition in the study environment .

4. Conclusion

Microbial structure are in different type, it is reflected in their behaviour and movement in soil, most cases they are influenced by lots of formation variable at various structural setting of the soil in the study area, the decay phase condition of the microbes in most occasion are determined by the rate of soil structural characteristics at different stratum of the formation, the study centred on the decay state of the microbes, permeability and porosity were major structural characteristics that influences the thermotolerant in the study environment, the influences from these two variables determine to an extend the rates of concentration including transport level of the microbes in the study area, such circumstance mean that the movement of thermotolerant are pressured by the level of porosity and permeability degree in the different stratum, geological setting may deposit homogeneous formation in some region of the study location , this may pressure the state of decay phase on the microbes, monitoring the level of decay phase at various formation of the soil need a serious approach to ensure it generates thorough results. Modelling the decay phase of thermotolerant need serious assessment which was done to ensure that every influential parameters are fully represented, the express derived solution generated the model in various phase to ensure that every behaviour from formation influences are represented in the model, finally all the developed model were incorporated to produces the final model to monitor decaying state of the microbes in homogeneous silty and fine sand formation

References

[1] Okpokwasili G.C. and Nweke C.O**.** 2005 Microbial growth and substrate utilization kinetics African Journal of Biotechnology Vol.5 (4), pp. 305-317, 16 February, 2005

[2] Ellyn M. M and Timothy R. G (2000) Modelling microbial processes in porous media Hydrogeology Journal 8:142–158

[3] Gerba, C. P. and Bitton, G. (1984). Microbial pollutants: their survival and transport pattern to groundwater. Groundwater Pollution Microbiology. Bitton, G. and Gerba, C. P. New York, NY, John Wiley and Sons**:** 65-88.

[4] Harvey, R. W. (1997). In Situ and laboratory methods to study subsurface microbial transport. Manual of Environmental Microbiology. McInerney, M. J. and Hurst, C. J. Washington, D.C., ASM Press**:** 586-599.

[5] Jin, Y., Chu, Y. J. and Li, Y. S. (2000). "Virus removal and transport in saturated and unsaturated sand columns." J Contam Hydrol **43**(2): 111-128.

[6] Klein, J. and Ziehr, H. (1990). "Immobilization of Microbial-Cells by Adsorption." Journal of

Biotechnology **16**(1-2): 1-16.

[7] Krekeler, C., Ziehr, H. and Klein, J. (1991). "Influence of Physicochemical Bacterial Surface-Properties on Adsorption to Inorganic Porous Supports." Applied Microbiology and Biotechnology **35**(4): 484- 490.

[8] Newby, D. T., Pepper, I. L. and Maier, R. M. (2000). Microbial Transport. Environmental Microbiology. Maier, R. M., Pepper, I. L. and Gerba, C. P. San Diego, Academic Press**:** 147 - 175.

[9] Gerba, C. P. (1984). "Applied and Theoretical Aspects of Virus Adsorption to Surfaces." Advances in Applied Microbiology **30**: 133-168

[10] Dowd, S. E. and Pillai, S. D. (1997). "Survival and transport of selected bacterial pathogens and indicator viruses under sandy aquifer conditions." J Environ Sci Health Part A-Environ Sci Eng Toxic Hazard Subst Control **32**(8): 2245-2258.

[11] Fontes, D. E., Mills, A. L., Hornberger, G. M. and Herman, J. S. (1991). "Physical and Chemical Factors Influencing Transport of Microorganisms through Porous-Media." Appl Environ icrobiol **57**(9): 2473-2481.

[12] Powelson, D. K., Simpson, J. R. and Gerba, C. P. (1991). "Effects of Organic-Matter on Virus Transport in Unsaturated Flow." Appl Environ Microbiol **57**(8): 2192-2196.

[13] Sobsey, M. D. (1979). "Detection of Enteric Viruses in Solid-Waste Landfill Leachates - Response." American Journal of Public Health **69**(4): 390-390.

[14] Yates, M. V. and Yates, S. R. (1988). "Virus Survival and Transport in Ground-Water." Water Sci Technol **20**(11-12): 301-307.

[15] Sinton, L. W., Noonan, M. J., Finlay, R. K., Pang, L. and Close, M. E. (2000). "Transport and attenuation of bacteria and Bacteriophages in an alluvial gravel aquifer." N Z J Mar Freshw Res **34**(1): 175- 186.

[16] Pedley, S. and Howard, G. (1997). "The public health implications of microbiological contamination of groundwater." Q J Eng Geol **30**: 179-188.

[17] David E. J (2003). Transport and survival of water quality indicator microorganisms in the ground water environment of Florida: Implications for aquifer storage and waste disposal *Theses and* Dissertations. University of South Florida