Open Journal of Waste Management and Environmental Protection
Vol. 1, No. 1, October 2013, PP: 1 - 14
Available online at http://scitecpub.com/Journals.php

Research article

PREDICTIVE MODEL TO MONITOR THE MIGRATION OF VIRUS IN HETEROGENEOUS FORMATION IN AHOADA EAST, RIVERS STATE OF NIGERIA

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Abstract

Virus is one of the major contaminants that pollute groundwater, this type of contaminant are known to migrate to a very deep formation, the death rate is very low compared to other contaminants due to its rate of transport, the rate of the virus contaminating groundwater is very high compared to other microbes. In most conditions when there is deposition of substrate utilization in the soil, it is prone to increase in microbial population and energy; it will also increase rapidly in concentration. The study area that is predominant with deltaic formation develops high concentration of virus contaminants. This is due to high deposition of environmental influence, to monitor the behaviour of this contaminant; mathematical model techniques were developed to solve the problem of virus transport in soil and water environment. To develop the model, environmental influence from different sources were considered. The behaviour of the virus on transport process were also considered in the system, every parameters that influence the transport system were integrated, these were carried out by putting the variables into mathematical equation, the derived equation generated a model that will solve the problem of virus contaminating soil and water in the study area.

Keywords: water, environment, soil, Nigeria

1. Introduction

Virus is one of the major pollutants in surface and groundwater, the area under study and found to be influenced with different types of pollution in surface and groundwater. Pollution is generated from various sources, groundwater is one of the sources where there are high rate of virus contaminant. This is one contaminant migrates to a very deep depth in the soil. The transport of virus in heterogeneous formation is influenced by the geological formation and it's characteristic. Heterogeneous aquifer in groundwater has lots of challenges in design and construction, quality water for human consumption and utilization has face tremendous challenges, this ugly siege has recorded high rate of water related disease causing thousands of deaths every year. Ahoada East is in deltaic environment that transit from Benin formation to sombrero, the characteristics of sombrero in most groundwater site from observation is heterogeneous deposit heterogeneous formation. In this condition it becomes a serious challenge to abstract groundwater, the deposition from aquiferous zone is in shallow depth, but the heterogeneous nature of the formation developed heterogeneous aquiferous zone. Stratification of the stratum from physical observation is through the disintegration of the sediment sand stone zone. The porous medium through the intercalation within the sediments is from sample gotten from the study area.

Microbiological pollution derived mostly from human and animal activities such as, unsewered settlements; on-site hygiene; cemeteries; waste disposal; waste disposal; Feedlots; etc. Microorganisms definitely will be the overriding forms of life and, in most cases; they will be the only forms of life present in aquifers. Nevertheless, with very few exceptions the only waterborne microbial pathogens of man are imperative human bacteria, viruses and protozoa, and in bearing in mind the safety of drinking water from the Point of view of infectious diseases one can almost completely overlook any source of infectious agents except human excreta. In relation to microbial contamination of groundwater it is therefore only essential to ensure that at the point of extraction no pollution with human excreta occurs. What most people do not know is that all groundwater naturally contains bacteria from various families and occasionally in very high numbers. Although the original water source may be without bacteria, the largest reservoir of bacteria is the soil zone. As a result, shallow as well as deep aquifers all show a variety and diversity of bacterial populations. Certain naturally occurring organisms which, for example, form a part of the nitrification/denitrification cycle, can be pathogenic under certain conditions. The factors that control the transport of bacteria through porous media are not well understood while the study of microbial movement in the field under unsaturated flow situation has received only restricted study to date. Advection, dispersion, deposition (clogging) and entrainment (declogging) are all processes that affect transport in noticeable ways. The outbreaks of typhoid fewer at the turn of the century from eating raw vegetables grown on soil fertilised with raw sewage resulted in extensive studies of the survival of enteric bacteria in soil (Gerba, Wallis & Melnick, 1975). Viruses are more resistant to environmental changes and may have a larger lifespan in the subsurface than bacteria. In most cases it appears that 60 - 90 days are sufficient for reduction of pathogens to negligible numbers once they have been to the soil, although survival times as long as five years have been reported. In a natural ecosystem (i.e. the subsurface) populations of the many different organisms interact in many ways. These interactions may be negative (decreased growth rate) or positive (increased growth rate) for one or all the different populations in the subsurface. In very low populations there is little or no interaction.

At some somewhat higher populations, positive interaction may predominate and the growth rate may increase. At maximum population, negative interaction like nutrient exhaustion and production of toxic metabolites, begin to predominate (Updegraff, 1991). Well water is more likely to be infected by viruses than by bacteria from an onsite Wastewater system. The greater infectivity of viruses contributes further to the health risk posed by viruses. For these reasons, the calculations in the procedure protect against viruses as well as bacteria. A waterborne virus and four potentially waterborne virus families were considered for the Guidelines: adenoviruses, enteroviruses, hepatitis A virus, nor viruses and rotaviruses. These were selected because the global literature and public Health authorities recognize them as actual, or potential, waterborne viruses that could Cause illnesses in New Zealand, as well as non-bacterial gastroenteritis and hepatitis A. This section provides basic information about the five virus groups, including the symptoms of any associated illness following contamination. Advice should be sought from the suitable district health board if further information about viruses is required. Adenoviruses contaminate a wide range of mammals, birds and amphibians, as well as humans. The types of the virus that contaminate humans are about 80.–90 nm (10-9 m) in diameter. Information about the frequency of adenoviruses in drinking water sources is very limited. These viruses cause a range of infections of the gastrointestinal tract, respiratory tract, urinary tract and the eyes, and are an important source of childhood gastroenteritis. They frequently cause respiratory illness, but enteric (intestinal) adenoviruses are a major cause of gastroenteritis worldwide. The diversity of adenoviruses species means that infection is possible by a number of routes. Consuming food or water contaminated by the virus may be an important source of gastro-enteric illness, although there is no substantial evidence supporting this transmission route. Epidemics of febrile disease (disease characterised by fever) with conjunctivitis are associated with waterborne transmission of some adenovirus types through contact recreation (e.g. inadequately chlorinated swimming pools and small lakes). The infective dose is believed to be low. Infants and children are the most susceptible to adenovirus infections, many of which are asymptomatic. Immunocompromised people are especially susceptible to severe complications of adenovirus infection. Groundwater is considered to be of excellent quality because of the soil barrier providing effective isolation of this high quality source water from surface pollutants. This is true for most groundwater resources although we know that many aquifers all over the world are polluted and/or is being polluted (Engelbrecht, 1993). Habitats containing only a single kind of microorganism are found only in the laboratory. Natural habitats contain many kinds of organisms which interact in complex ways. The great reservoir of bacteria in nature is the soil; it contains both the largest population and the greatest variety of species. Most bacteria that are found in surface waters are derived from the soil.

However, the quality of subsurface waters may be impacted both by naturally occurring processes as well as by actions directly attributable to human activities. In the past, the main driving force for hydrogeologic studies has been the need to assess the water-supply potential of aquifers. During the past 20 years, however, the emphasis has shifted from water-supply problems to water-quality problems. This has driven a need to predict the movement of contaminants through the subsurface environment. One consequence of the change in emphasis has been a shift in perceived priorities for scientific research and data collection. Formerly, the focus was on developing methods to assess and measure the water-yielding properties of high-permeability aquifers. Konikow 2002 The discharge of domestic wastewater to ground and the proximate abstraction of groundwater for domestic purposes can contaminate drinking water. Regional councils need to consider these situations when implementing the National Environmental Standard (NES) for Sources of Human Drinking Water (NZ Government, 2007). Separation distances between wastewater discharges and groundwater abstractions must be established to reduce the likelihood of contamination. Some regional council has specified separation requirements based on the transport of bacteria. Others have separation requirements with an uncertain scientific basis, and yet others have no separation requirements. Importantly, none of the existing separation distances allow for the influence of different subsurface materials on the transportation of viruses through the ground. Using bacterial rather than viral transport as the basis for guidelines is a shortcoming for two main reasons. The survival characteristics of viruses favour their transportation over long distances in aquifers, and their high infectivity means they can cause disease, even though their numbers may have been substantially reduced during transport.

Furthermore, virus concentrations are reduced more effectively by some subsurface materials than others. The use of arbitrary separation distances that take no account of differences in these materials may over- or under-protect water resources. Among the many waterborne pathogens of humans, enteric viruses have the greatest potential to move deeply through the subsurface environment, penetrate aquitard, and reach confined aquifers. Enteric viruses are extremely small (27-75 nm), readily passing through sediment pores that would trap much larger pathogenic bacteria and protozoa. Viruses have been found in groundwater at depths of 67 m (Keswick and Gerba 1980; Robertson and Edberg 1997) and 52 m (Borchardt et al 2003) and lateral transport has been reported as far as 408 m in glacial till and 1600 m in cracked limestone (Keswick and Gerba 1980). Several recent studies have demonstrated widespread occurrence of viruses in domestic and municipal wells in the United States (Abbaszadegan et al 2003; Borchardt et al 2003; Fout et al 2003; Borchardt et al 2004, 2003,), and approximately half of waterborne disease outbreaks attributable to groundwater consumption in the United States have a viral etiology (National Primary Drinking Water Regulations, 2006). The US Environmental Protection Agency has listed several viruses on its drinking water pollutant Candidate List, emphasizing that waterborne viruses are a research priority (http://www.epa.gov/safewater/ccl/index.html). Although the susceptibility of groundwater to virus contamination is now recognized, the occurrence of viruses in confined aquifers has rarely been explicitly investigated. In the most comprehensive groundwater-virus study to date, Abbaszadegan and others (2003) sampled 448 groundwater sites in 35 states and found 141 sites (31.5%) were positive for at least one (Borchardt et al 2003, 2007). acquaintance about the local hydrogeologic system and virus survival time makes some of these conceptual models more probable than others. The only environmental source of human enteric viruses is human fecal waste, and within the city limits of Madison human fecal waste is presumably only present in sanitary sewers. From this presumed point of entry, viruses must travel downward over 200 feet though the upper sandstone aquifer, an additional 10 to 30 feet downward through the Eau Claire aquitard to reach the top of the Mount Simon aquifer. Once in the Mt Simon aquifer the viruses must move laterally some unknown distance to the production wells. Based on such a travel path,

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pathway seems very unlikely because travel times would likely be far longer than the six months to two years these viruses can survive in the environment (Yates and others 1985, John and Rose 2005, Schijven and others 2006).

2. Theoretical back ground of the model

The transport of virus in heterogeneous formation may fluctuate on the transport process, or even lag in some instant, this condition are generated from the influence of heterogeneous deposition in the study area. To monitor the rate of virus in the study location, we consider the variables to be expressed applying mathematical tools, heterogeneous nature of the formation that influence the aquifer, were considered to be able to monitor the migration of the virus, and determine its behaviour at every stratum in the study area. Mathematical expression were applied to model the behaviour of the virus, this condition considered the variables in the system by applying plug flow system which is the basic application of these model. Heterogeneous formation in some instances produces fluctuation results on the process of migration to ground aquifer. To predict the behaviour the system the following mathematical tools and is variables were expressed denoted as;

The variables are as follows:

D = Dispersion coefficient

U = Velocity transport

C = Concentration

φ = Porosity of soil

t = Time

x = Distance

3. Developed Model

$$\frac{D\partial^2 C}{\partial x^2} = \frac{U\partial C}{\partial x} + \frac{\phi\partial C}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

This equation were put together to monitor the migration of various of condition of the virus considering heterogeneous formation, these variables are presented in the equation; this equation derived will monitor the transport of virus in heterogeneous formation.

To mathematically derive the equation, the expression can be applied using physical splitting techniques on equation (1), we have

$$\frac{U\partial^2 C_1}{\partial x^2} = U\frac{\partial C_1}{\partial x} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (2)$$

$x = 0$

$C(o) = Co = 0$

$$\frac{\partial C_1}{\partial x} / \; x = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (3)$$

$$\frac{D\partial^2 C_2}{\partial x^2} = \frac{\phi\partial C_2}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (4)$$

Equation (4) implies that the contaminants are in progressive phase condition, the variable definitely may influence the contaminant migration, the system is a continuous process, where by the migration of the contaminant is from one soil formation to the other, the concentration [C] may be influenced by the [φ] porosity. The porosity of the formation under study is very high and at progressive phase of the transport, fast migration is influenced by high degree of the porosity of the soil, the migration varies in time and distance.

Expressing the boundary values

$x = 0$

$t = 0$

$C(o) = Co = 0$

$$\frac{\partial C_1}{\partial x} / \; x = 0, B \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (5)$$

The splitting of the variables, continued to express in different conditions based on the behaviour of the contaminant in the following dimension.

$$\frac{U\partial C_3}{\partial x} = \frac{\phi\partial C_3}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (6)$$

$x = 0$

$t = 0$

$C(o) = 0$ .... (7)

Applying direction integration on eqn (2)

$$\frac{D\partial C}{\partial x} = UC + K_1 \qquad (8)$$

The establishment of velocity of transport and the concentration allowed for the introduction of K as constant

Again, integrate equation (8) directly, yields

$$DC = UCx + K_1 x + K_2 \qquad (9)$$

Subject to equation (3) we have

$$DCo = K_2 \qquad (10)$$

And subjecting equation (8) to (3)

$$\frac{\partial C_1}{\partial x} / x = 0, = Co\ C(o) = Co$$

Yield

$$0 = UCo + K_2$$

$$\Rightarrow K_1 = UCo \qquad (11)$$

So that we put (10) and (11) into (4), we have

$$DC_1 = UC_1 x = UCox + DCo \qquad (12)$$

$$DC_1 - UC_1 x = DCo - UCox \qquad (13)$$

$$\Rightarrow C_1 (D - Ux) = Co(D - Ux) \qquad (14)$$

$$\Rightarrow \quad C_1 = 0$$

The boundary values are expressed with respect to the behaviour of the concentration at various conditions of the virus at different soil formations. The characteristics of the formation express the limit, this condition denote the boundary values expressed in equations (12) and (13) above. But at a certain region, the applying of plug flow system the process of transport form one region to the other, become real as the variable in the system influence the soil behaviour, this may allow for constant concentration on the transport process, whereby the influence of alluvium deposition in some formation establishing such stratum in the soil. Hence, equation (14) entails in some conditions that at any given distance, x we have constant concentration of the contaminant in the system. Now, we consider equation (4) which is in progressive phase of the system expressed as:

$$\frac{D\partial^2 C}{\partial x^2} = \frac{\phi\partial C_2}{\partial t} \qquad \text{...} \qquad (14)$$

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

$$C_2 = XT \qquad \text{...} \qquad (15)$$

$$\frac{\partial^2 C}{\partial x^2} = X''T \qquad \text{...} \qquad (16)$$

$$\frac{\partial C_2}{\partial t} = XT' \qquad \text{...} \qquad (17)$$

Put (16) and (17) into (15), so that we have

$$DX''T = \phi XT' \qquad \text{...} \qquad (18)$$

i.e. $$\frac{DX''}{X} = \phi\frac{T'}{T} = -\lambda^2 \qquad \text{...} \qquad (19)$$

Hence $$\frac{DX''}{X} + \lambda^2 = 0 \qquad \text{...} \qquad (20)$$

i.e. $$X'' + \frac{\lambda^2}{D}X = 0 \qquad \text{...} \qquad (21)$$

And $\phi T' + \lambda^2 T = 0$ ………………………………………………… (22)

From(21), $X = A Cos \frac{\lambda}{\sqrt{D}} x + \beta Sin \frac{\lambda}{\sqrt{D}} x$ ………………………………… (23)

And (16) give

$$\boxed{T = C\ell^{\frac{-\lambda^2}{\phi}t}}$$ …………………………………………………….. (24)

These conditions are influenced by Time with respect to the concentration in exponential condition. In some condition the formation history influenced the soil, the influence of geologic history in these condition implies that the formation characteristics that independent variables in the system may be very high, and that will definitely influence the virus, to migrate fast and contaminant groundwater aquifer. Porosity is the rate of micropore between the intercedes in the soil structural deposition, the rate of disintegration from the sedimentary deposition, may develop low consolidation compare to other types of rocks, the disintegration level determine the rate of stratification of the formation, these condition also influenced the rate of porosity of the stratum. The transport of the contaminant maintained the law of plug flow. The migration from one formation to another definitely makes the rate of the contaminant concentration in transport system and population increase. The model expressing equation (24) further is to accommodate the variables that influence the contaminant, so we put (25) and (24) into (15), we get

$$C_2 \left(A Cos \frac{\lambda}{\sqrt{D}} x + \beta Sin \frac{\lambda}{\sqrt{D}} x \right) C\ell^{\frac{-\lambda^2}{\phi}t}$$ …………………………………………… (25)

The condition denotes (D), Dispersion that also influence the contaminant to spread, while migrating to ground water aquifer, the contaminant, at this level are still on progress phase, but spread while migrating in porous medium.

Subject equation (25) to condition equation (5), so that we have

$C_o = AC$ …………………………………… (26)

$\therefore$ Equation (26) becomes

$$C_2 = Co\ell^{\frac{-\lambda^2}{\phi}t} Cos\frac{\lambda}{\sqrt{D}}x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (27)$$

Again at

$$\frac{\partial C_2}{\partial x} / \ x = 0, B = 0, t = 0$$

Equation (27) becomes

$$\frac{\partial C_2}{\partial x} = \frac{\lambda}{\sqrt{D}} Co\ell^{\frac{-\lambda^2}{\phi}} Sin\frac{\lambda}{\sqrt{D}}x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (28)$$

i.e. $$0 = \frac{Co\lambda}{\sqrt{D}} Sin\frac{\lambda}{\sqrt{D}}0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

$$\frac{Co\lambda}{\sqrt{D}} \neq 0$$

Considering (NKP) which is the substrate utilization for virus growth (population), so that the energy gotten from the microelement will increase the growth and population of the virus, these condition implies that the equation will be expressed in these form

At $$0 = -\frac{Co\lambda}{\sqrt{D}} Sin\frac{\lambda}{\sqrt{D}}B \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

$$\Rightarrow \frac{\lambda}{D} = \frac{n\pi}{2}, \ n = 1,2,3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (31)$$

The continuous process of migration in x direction varies with different soil stratification at different void ratio, permeability and porosity. This variable will definitely influence the migration of the contaminant in concentration in different soil formation, thus to migrate, at dynamic level in x direction. So that the equation can be expressed as:

$$\Rightarrow X = \frac{n\pi\sqrt{D}}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (32)$$

So that equation (27) becomes

$$C_2 \quad = \quad C_o \, \ell^{\frac{-n^2\pi^2 D}{2\phi}} \; Cos \; \frac{n\pi\sqrt{D}}{2\sqrt{D}} x \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (33)$$

$$\Rightarrow \; C_2 \quad = \quad C_o \, \ell^{\frac{-n^2\pi^2 D}{2\phi} t} \; Cos \; \frac{n\pi}{2} x \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (34)$$

Now we consider equation (6) which is the steady-flow state of the system

Using Bernoulli's method, we have

$$C_3 \quad = \quad XT \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (35)$$

$$\frac{\partial C_3}{\partial x} \; = \; X'T \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (36)$$

$$\frac{\partial C_3}{\partial t} \; = \; XT' \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (37)$$

Put (35) and (36) into (6), so that we have

$$UX'T \quad = \quad -\phi XT' \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (38)$$

i.e. $$\frac{UX'}{X} \quad = \quad -\phi \frac{T'}{T} \varphi \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (39)$$

$$\frac{UX'}{X} \quad = \quad \varphi \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (40)$$

$$-\phi \frac{T'}{T} \quad = \quad \varphi \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (41)$$

$$X \quad = \quad A\ell^{\frac{\varphi}{U}x} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (42)$$

And $$T \quad = \quad \beta\ell^{\frac{\varphi}{U}t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (43)$$

Put (41) and (42) into (34) gives

$$C_3 \quad = \quad A\ell^{\frac{\varphi}{U}t} \qquad \ldots\ldots\ldots\ldots \qquad (44)$$

Subject equation (43) to (7), yield

$$C_3(o) \quad = \quad Co \qquad \ldots\ldots\ldots\ldots \qquad (45)$$

So that equation (45) becomes

$$C_3 \quad = \quad Co\ell^{(x-t)\frac{\varphi}{U}} \qquad \ldots\ldots\ldots\ldots \qquad (46)$$

The expression of all the variables consider steady state condition in the system, the condition of the contaminants in the system may be due to the rate of stratification deposition of the soil, such formation characteristics in some region may generate steady state, where the contaminant may experience lag phase in those formation, the derived equation accommodates the variation of the soil in terms of stationary phase due to the influence from the soil characteristics. These condition consider the condition where there is no substrate utilization deposited, it implies that the contaminant will not have any microelements to feed and increase in microbial population, the microbes will experience degradation, if they can not adapt at the region, the contaminants will migrate to the next formation where they find source of microelement to feed and increase in there population, the system considered these condition in the system, the microelements may not deposited in some region, considering stationary phase the mathematical expression in the system, assuming that at the steady state flow, there is no (NKP) for substrate utilization, our concentration here is zero, so that equation (45) become

$$C_3 \quad = \quad 0 \qquad \ldots\ldots\ldots\ldots \qquad (47)$$

Therefore solution of the system is of this form

$$C = C_1 \; C_2 + C_3 \qquad \ldots\ldots\ldots\ldots \qquad (48)$$

We now substitute (14), (33) and (46) into (47), so that we have the model of the form

$$C_2 \quad = \quad C_o \, \ell \frac{-n^2 \pi Dt}{2\phi} \; Cos \, \frac{n\pi}{2} x \qquad \ldots\ldots\ldots\ldots \qquad (49)$$

$$\Rightarrow \; C \quad = \quad C_o \left(1 + \ell \frac{-n^2 \pi D}{2\phi} \; Cos \, \frac{n\pi}{2} x \right) \qquad \ldots\ldots\ldots\ldots \qquad (50)$$

The final model express the solution of the contaminant considering all condition of the soil, all the variables were mathematically expressed, the behaviour of virus migration from the surface of the soil to aquiferous zone has been thoroughly expressed through the derived mathematical model, the developed model considered the variation through the geological history in the study area, the contaminant are influenced by the formation characteristic including porosity, void ratio and permeability. These parameters influenced the soil stratification that varies in deposition at different formation, these formation characteristics are the major influences considered in the system, this parameters determines the behaviour of virus in terms of transport to groundwater aquifer. The model considered all these conditions through the mathematical tools applied that denotes all mathemathical symbols, the parameters considered the stated model equation as a model that determine the rate virus contaminating soil and water, this model can be stimulated for validation.

4. Conclusion

Predictive model to monitor the migration of virus in heterogeneous formation has been developed; the mathematical expression was developed considering all the variables in the system. The variables considered in system are base on the behaviour of the virus, through the stratification deposition of the soil structure, these formation characteristics were denoted as a parameter using mathematical symbols. The equation that generated the model were derived considering the behaviour in a splitting unit at each phase and condition of the virus, the model expressed consider the soil stratification in the system, the developed model considered these independable variables, because they are the major influence of fast migration of the virus through structural deposition of the soil in the study area. The model developed will be a benchmark for practicing Engineers to design and construct groundwater system considering the behaviour of the contaminant in order to prevent the virus from contaminating aquiferous zone.

References

[1] Engelbrecht, J.F.P., 1993. An assessment of health aspects of the impact of domestic and industrial waste disposal activities on groundwater resources. ISBN 1-86845-028-7.

[2] Updegraff, D M., 1991. Background and practical applications of microbial ecology in modeling the environmental fate of microorganisms, Ed, C J Hurst. American Society for microbiology, ISBN 1-55581-031-4, 1991.

[3] GERBA, C.P., WALLIS, G. and MELNICK, J.L., 1975. Fate of wastewater bacteria and viruses in soil. Journal of the irrigation and drainage division. American Society of Civil Engineering, Vol. 101, pp 157-174.

[4] McNABB, J.F. and DUNLAP, W.J., 1975. Subsurface biological activity in relation to groundwater pollution. Ground Water Vol. 13 no. 1. January - February 1975.

[5] Catha M Chris N Moore C Lipping P Viv S and Susie O Guidelines for separation distance based on virus transport between onsite domestic wastewater and well, environmental science and research limited, New Zealand.

[6] Konikow L F use of numerical models to simulation ground water flow transport: us geological surveyor virginal USA 2010.

[7] Abbaszadegan, M., M. LeChevallier, and C. Gerba. 2003. Occurrence of viruses in US groundwaters. Journal of American Water Works Association. 95:107-120

[8] Borchardt MA, Bradbury KR, Gotkowitz MB, Cherry JA, and Parker BL. 2007a. Human enteric viruses in groundwater from a confined bedrock aquifer. *Environmental Science and Technology* 41:6606-6612.

[9] Borchardt MA, Spencer SK, Harrington GW, Bertz PD, Volenec MJ, Kieke BA Jr., Lambertini E, and Loge FJ. 2007b. Inputs of viruses into municipal drinking water: contaminated groundwater versus distribution system intrusions. Poster presented at the American Society for Microbiology, Toronto, Ontario, May 21- 25, 2007.

[10] Borchardt MA, Haas NL, Hunt RJ. 2004. Vulnerability of municipal wells in La Crosse, Wisconsin, to enteric virus contamination from surface water contributions. *Applied and Environmental Microbiology* 70: 5937-5946.

[11] Borchardt MA, Bertz PD, Spencer SK, Battigelli DA. 2003 Incidence of enteric viruses in groundwater from household wells in Wisconsin. Applied and Environmental Microbiology 69:1172-1180.

[12] Fout, G.S., B.C. Martinson, M.W.N. Moyer, and D.R. Dahling. 2003. A multiplex reverse transcription-PCR method for detection of human enteric viruses in groundwater. Appl. Environ. Microbiol. 69:3158-3164.

[13] John, D.E. and J.B. Rose. 2005. Review of factors affecting microbial survival in groundwater. Environ. Sci. Tech. 39:7345-7356.

[14] Madison Metropolitan Sewerage District (MMSD), 2008. Metro Interceptor (newsletter). Summer/Fall 2008 issue. p 4.

[15] Schijven, J.F., J.H.C. Mülschlegel, S.M. Hassanizadeh, P.F.M. Teunis and A.M. de RodaHusman. 2006. Determination of protection zones for Dutch groundwater wells against virus contamination – uncertainty and sensitivity analysis. J Water Health 4:297-312.

[16] Yates, M.V., C.P. Gerba, and L.M. Kelly. 1985. Virus persistence in groundwater. Appl. Environ. Microbial. 49:778-781.