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Research article

MODELING OF BATCH SYSTEM ON LEGIONELLA TRANSPORT INFLUENCED BY PERMEABILITY IN HOMOGENOUS FINE SAND IN BAKANA, RIVERS STATE OF NIGERIA

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Abstract

Mathematical modeling to monitor the effect and behavior of legionella has been carried out, this type of microbial specie were found to be predominant in the study area contaminating ground water aquifer, the derive model expressed the concentration of the contaminant under the influence of formation characteristics such as porosity and degree of saturation, high rate of degree of saturation were found to play a major role on the transport of microbes between the flow net. Stratification of this soil determine the degrees of permeability and porosity, this generate high percentage of hydraulic conductivity of water at aquiferous zone. Since the microbes are found in fluids, the pressure of this fluid flow are determine by this formation characteristics, thus the contaminant on the fluid migrate through the flow net at various formation and pollute the ground water aquifers. It is recommended that construction materials should be apply base on the stipulated standard carried out to design quality ground water for human utilization.

Keywords: microbial, water aquifers, ground water

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1. Introduction

Soil water regime is highly affected by soil structure and its stability. Various soil structure types may cause preferential flow or water immobilization [kodesova et al 2006, kodesova et al , kodesova et al 2009a]. Soil structure breakdown may initiate a soil particle migration, formation of less permeable or even impermeable layers and consequently decreased water fluxes within the soil profile [kodesova et al 2009b]. Soil aggregation is under control of different mechanisms in different soil types and horizons [strudley et al 2008]. Soil structure and consequently soil hydraulic properties of tilled soil varied in space and time [chan et al1994]. The temporal variability of the soil aggregate stability was shown for instance by [Yang and Wander, 1998, Murphy et al 1993]. While [Yang and Wander,1998] documented that temporal changes of aggregate stability were not positively related to living root length density; [messing and Jarvis, 1993] suggested that the higher aggregate stability was found due to crop roots, exudates microbial by-products and wet/dry cycles. The temporal variability of the soil hydraulic properties (mainly hydraulic conductivities, *K*) were investigated for instance in following studies. [Somarantne and smrttem, 1993] Showed that *K* values at tensions of 10 and 40 mm varied temporally due to the tillage, wetting/drying, and plant growth. [Angulo, et al 1997] Presented that the *K* values decreased during the growing season due to the structural breakdown by rain and surface sealing. [Angulo, et al 1997] Documented that while the *K* values at tension of 20 mm were reduced due to the raindrop impact, the *K* values at tension of 40 mm were not influenced. [Peterson et al, 1997] Discovered that only the more homogeneous sandy soil under furrow irrigation exhibited significant decrease in sorptivity. [bonder et al 2008] Documented using the dye tracer experiment that cultivation reduced the number of active preferential flow paths. [bonder et al2008] Measured tension infiltration from 0 to 90 mm and showed that macropore flow decreased from 69% in July to 44% in September.[suwradji and Eberbach, 1998] discussed the impact of the rainfall intensity, soil drying and frost on the seasonal changes of soil hydraulic properties in the structure-related range. Finally, [Haas et al 1999] studied both, aggregate stability and hydraulic conductivities. They documented the lowest aggregate stability during the winter and increased in spring. The *K* values decreased during the growing season. The goal of this study is to assess the seasonal variability of the soil structure, aggregate stability and hydraulic properties with respect to each other and to varying soil physical and chemical properties, soil management Soil passage is frequently used as pretreatment in production of drinking water in The Netherlands in river bank filtration (RBF; 5%) and artificial recharge (AR) in open basins (13%) or deep wells (1%) by several water suppliers. It is an intensive filtration process with long contact times and an effective barrier for pathogenic micro-organisms such as viruses, bacteria, and protozoa. How effective it is, however, is not known and is a question of growing interest since the introduction of quantitative microbial risk assessment for drinking water safety [Anonymous, 19980]. In 1980 a minimum water travel time of 60 days as a protection zone around groundwater abstraction wells was formalized in The Netherlands Anonymous,[Knorr, 1937]. This travel time was assumed to cause sufficient die off of pathogenic Soil passage is frequently used as pretreatment in production of drinking water in The Netherlands in river bank filtration (RBF; 5%) and artificial recharge (AR) in open basins (13%) or deep wells (1%) by several water suppliers. It is an intensive filtration process with long contact times and an effective barrier for pathogenic micro-organisms such as viruses, bacteria, and protozoa. How effective it is, however, is not known and is a question of growing interest since the introduction of quantitative microbial risk assessment for drinking water safety [Anonymous, 19980]. In 1980 a minimum water travel time of 60 days as a protection zone around groundwater abstraction wells was formalized in The Netherlands [,[Knorr, 1937]. This travel time was assumed to cause sufficient die off of pathogenic bacteria from contamination sources [Craun et al1997]. In the past decades, however, viruses, and more recently protozoa like *Cryptosporidium* and *Giardia*, have been recognized as pathogens of major concern in the water industry [Mackenzie et al 1994, Gerba and Rose, 1990, and Schijven and hoogenboezem et al 1999]. These organisms have been related to waterborne diseases because of their persistence in the environment, resistance to water treatment, and high infectivity. These organisms are different from bacteria in survival, surface properties, and size. Moreover, it has become clear that die off in groundwater is not the only process that governs the transport of microorganisms. For viruses it was demonstrated that attachment to soil particles was more important than survival in the groundwater [Schijven and hoogenboezem et al 1999]]. Therefore, viruses and maybe protozoa could be transported over longer distances in soil and thus be more significant to the microbial safety of groundwater. To verify the safety of the 60-days set back distance guideline, but also to assess the microbial safety of vulnerable groundwater systems and of RBF and AR systems with shorter water travel times, more quantitative information is needed on the elimination capacity of soil passage systems. A number of field studies have been carried out that established either removal of indigenous micro-organisms or lab-cultured seeded microorganisms [Schijven, 2001, Schijven, 2001, , Schijven 2003, Schijven 1999, and Schijven Schijven2000], . These studies showed that soil passage poses a very effective barrier to micro-organisms, but critical situations may arise [Schijven, 2001]. Such situations are intrusion of contaminations to unconfined aquifers above groundwater wells, water abstraction during RBF from a gravel aquifer, with increased risk during high flow events, or short circuiting during recollection in AR systems. Field studies are valuable but hampered by some drawbacks. The concentration of pathogens in the field is generally too low to assess removal, and only non hazardous model micro-organisms (*Escherichia coli*, Bacteriophages, and spores of clostridia) can be used in spiking studies [Schijven2003]. Moreover, the removal process is complex and influenced by a range of factors which vary considerably between sites. Hence, the effect of specific conditions such as soil characteristics, water velocity, and water quality variations are difficult to assess under field conditions [Schijven ,2003, Medema, et al1997] .

2. Materials and Method

Column experiments were also performed using soil samples from several borehole locations, the soil samples were collected at intervals of three metres each (3m). An legionella solute was introduced at the top of the column and effluents from the lower end of the column were collected and analyzed for legionella and the effluent at the down of the column were collected at different days, analysis, velocity of the transport were monitored at different days. Finally, the results were collected to be compared with the theoretical values.

3. Theoretical Background

$$K\,C_{(x)}\frac{\partial V_{(x)}}{\partial t} = V\frac{\partial C_{(x)}}{\partial t} \quad \dots\dots\dots\dots\dots\dots\dots\dots \quad (1)$$

$$\frac{\partial V_{(x)}}{\partial t} = K\,C_{(x)}\frac{\partial V_{(x)}}{\partial t} \quad \dots\dots\dots\dots\dots\dots\dots\dots \quad (2)$$

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

$$V\!\!\diagup\!\! V_x \,\frac{\partial C_{(x)}}{\partial (x)} = -\frac{Kdt}{t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (4)$$

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

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

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

$$\frac{C_{(x)}}{C_{(x)_o}} = \left(\frac{t}{t_o}\right) - \frac{KV_x}{V} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (8)$$

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

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

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

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

The model will be used to determine the Rte of E. coli Transport influenced by permeability.

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

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

Take Laplace Transform of (13) we have

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

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

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

By applying quadratic formula in (15), we have

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

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

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

Now the general solution of (16) is

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

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

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

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

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

4. Results and Discussion

Modeling of batch system on legionella transport influenced by permeability in homogenous fine sand are presented in tables and figures.

Table 1: Comparison of theoretical and Experimental values of legionella at various Times

Time	Theoretical values	Experimental values
10	2.24E-06	2.43E-06
20	6.10E-10	6.24E-10
30	1.50E-12	1.34E-11
40	4.50E-16	4.44E-13
50	1.40E-19	1.34E-17
60	7.49E-25	7.78E-23
70	2.40E-28	2.56E-24
80	5.32E-32	5.45E-32
90	3.01E-15	3.44E-14
100	2.36E-10	2.23E-09

Table 2: Comparison of theoretical and Experimental values of legionella at various Times

Time	Theoretical values	Experimental values
10	5.6	6.12
20	2.5	2.7
30	1.68	1.88
40	1.28	1.12
50	1.01	0.99
60	0.84	0.78
70	0.72	0.75
80	0.63	0.56
90	0.56	0.53
100	0.51	0.49

Table 3: Comparison of theoretical and Experimental values of legionella at various Times

Time	Theoretical values	Experimental values
10	2.32	2.25
20	1.16	1.12
30	0.76	0.66
40	0.58	0.54
50	0.46	0.49
60	0.38	0.31
70	0.33	0.29
80	0.29	0.26
90	0.25	0.21
100	0.23	0.26

Table 4: Comparison of theoretical and Experimental values of legionella at various Times

Time	Theoretical values	Experimental values
10	5.91	5.24
20	4.96	4.44
30	3.31	3.25
40	2.48	2.34
50	1.98	1.66
60	1.65	1.45
70	1.42	1.26
80	1.24	1.19
90	0.19	0.16
100	0.9	0.7

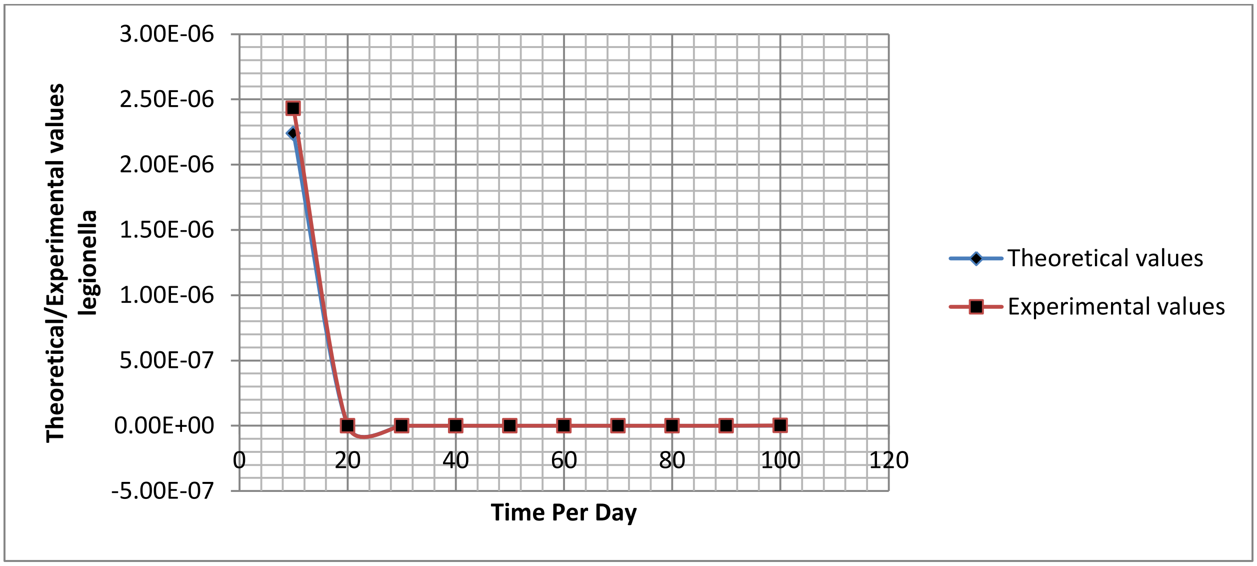

Figure 1: Comparison of theoretical and Experimental values of legionella at various Times

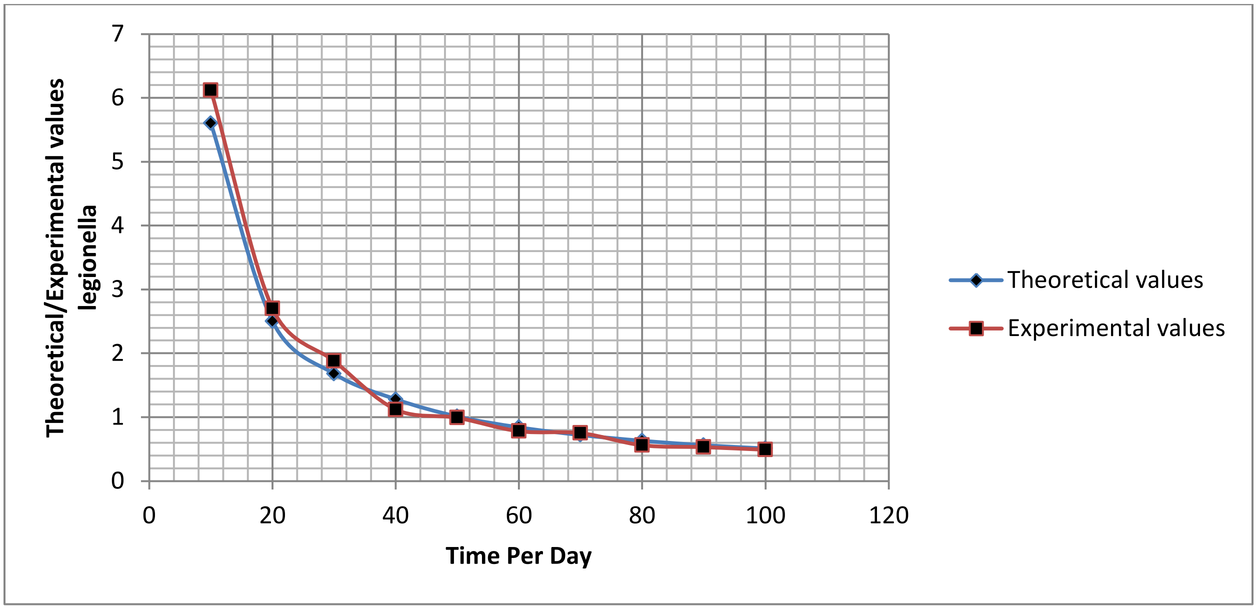

Figure 2: Comparison of theoretical and Experimental values of legionella at various Times

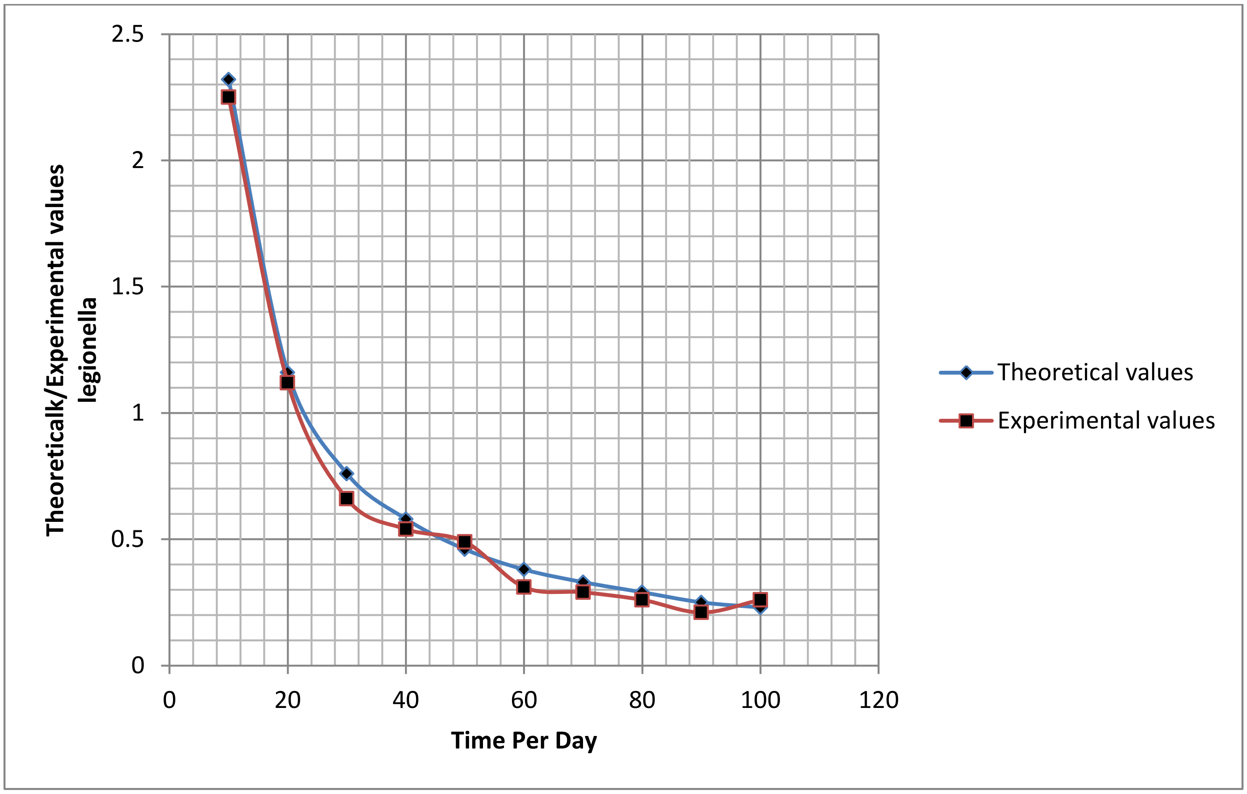

Figure 3: Comparison of theoretical and Experimental values of legionella at various Times

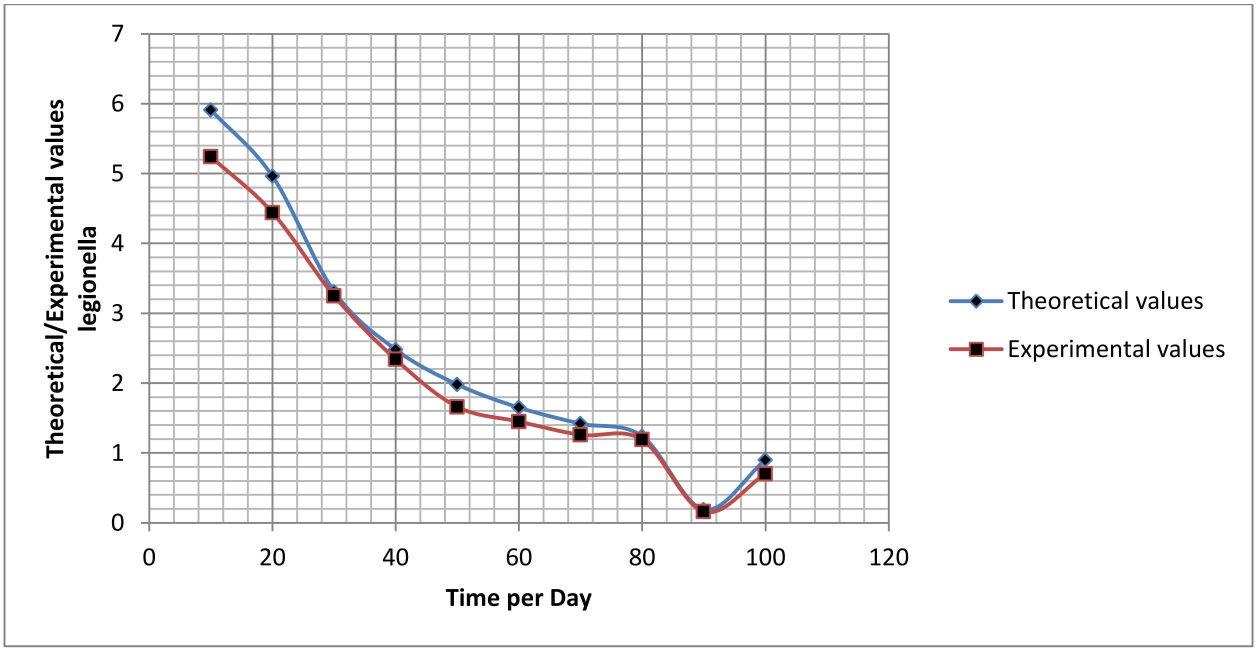

Figure 4: Comparison of theoretical and Experimental values of legionella at various Times

Physical process has been confirmed to influence the deposition of legionella as expressed in figure 1, rapid increase were observed at ten days between the lateritic soil monitored with respect to time, sudden degradation were observed at twenty days were constant concentration were maintained from thirty to one twenty days. This condition can be attributed to high rate of inhibitors that could not allow the microbes to increase in microbial population. Change in concentration were observed influenced by variation in soil structural deposition, under the influence of deposition of homogenous formation Figure 2 maintained similar condition whereby the theoretical values experience rapid migration at ten days, sudden degradation were observed between ten and thirty days, while gradual decrease were observed from forty to hundred days. Experimental values produce similar result as the maximum concentration were observed between ten and twenty days, while gradual decrease were experienced from forty to hundred days Figure 3 recorded an optimum value at ten day**s,** its experience sudden degradation from twenty down to the lowest concentration at hundred days, while the experimental values observed maximum concentration at ten days, sudden degradation were observed between twenty to hundred days with slight fluctuation. Homogenous nature of the soil was predominant base on the influence of alluvia deposition. Figure 4 produce high deposition of the microbes at ten days, slight vacillation were observed between ten and eighty days, while lag phase were observed at ninety days and finally it experience a slight insignificance increase at hundred days, while the experimental values obtained a rapid increase at ten days were initial concentration were recorded, slight fluctuation were recorded between thirty to eighty days and slight condition of lag phase were experience at ninety days, while it finally experienced insignificance slight increase at hundred days, physical process where expressed in all the figures at different formation, the inhibition of the metal play a major role were by the substrate utilization were found insignificance. The degree of saturation plays a major role through influence of high rain intensities. Microbial population and transport were confirmed to take advantage of the influence of degree of saturation, as initial concentrations are deposited between the lateritic zones of the soil. High velocities of transport were found to influence the change of concentration, decreasing at various depths. Regeneration of the biological waste cause high deposition of the contaminant producing concentration that is are between the aquiferous zone .

5. Conclusion

Models establishment to monitor the effect and behavior of legionella transport in soil and water environment has been expressed. Homogenous formations were confirmed to play a major role on physical process of concentration in the study area. Porosity and degree of saturation were confirmed to be a major variables that play a major role on this type of microbial specie in the study area, the concentration of the microbes establish slight variation under the influence of insignificant deviation between the intercedes of the soil. High production of contaminant develop constant increase of the pollutant at various formation, trace of this contaminant in the aquiferous zone are not between the stipulated standard in the formation, therefore it is recommended that thorough assessment for water quality should be systematically integrated in design of ground water system in other to avoid the spread of this type of microbial specie in the study area.

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