MODEL DEVELOPMENT APPROACH TO PREDICT THE BEHAVIOUR OF E-COLI TRANSPORT ON STATIONARY PHASE IN KHANA, DELTAIC ENVIRONMENT OF RIVERS STATE, NIGERIA

Eluozo, S. N1*, Ademiluyi, J. O1 and Nwaoburu A .O2

1Department of Civil Engineering, Faculty of Engineering, University of Nigeria Nsukka
2Department of Mathematics, Faculty of Science Rivers State University of Science and Technology Nkpolu, Port Harcourt

INTRODUCTION

The behaviour of microbes on stationary phase condition varies depending on their types, the migration of e-coli from one strata to another strata down to aquiferious zone also varies including velocity, that is why the condition of stationary condition of e-coli should be studied to find out the influence that cause the migrating to a certain point they find themselves stationing in some region , the study of this microbes behaviour considering this stationary phase condition is a method of understanding the kinetics condition, definitely there should a cause for it, these condition generate a lot of increase in population of microbes in a situation, where microbes station in a region, horizon where there is a deposition of Nitrogen, Phosphorus, Carbon etc, this micronutrients will definitely increase their microbial population, the condition may be in an aquiferious zone , such condition will increase the concentration of e-coli at that region of ground water aquifers , therefore the condition of e-coli in stationary phase is of serious concern, and call for extensive study in other to find a better solution that will be applied in solving the transport of e-coli at stationary phase condition at Khana deltaic environment, because the problem of abstracting quality ground water in some location at Khana in Rivers state has cause a lot of problem of developing potable water at those location affected at Khana the study result will generate a design parameter to be apply in those location the pollution are deposited, the alarming rate of water related diseases from those study location make the study imperative to find a lasting solution to this threat of life, the variation of this microbial on transport, implies that model of solving the transport of e-coli in deltaic environment must be thoroughly studied because of its heterogeneous behavior of its transportation to ground water aquifers in deltaic environment. More so other microbes that pollute ground water aquifers also cause their pollution in different dimension, Pathogenic microorganisms in groundwater are estimated to cause 750,000 to 5 million illnesses per year in the United States (Macler et al., 2000). The fate and transport of these microbes are dependent on their propensity to adhere to mineral surfaces. By studying this phenomenon, we gain insight not only into the mechanisms influencing pathogen transport but also into processes such as the initiation of infection (Prigent et al., 2000), biofilm formation (Espinosa et al., 1999), and the colonization of plant roots (Bloemberg et al., 1997).

Escherichia coli, a gram-negative bacterium, is considered an ideal indicator of fecal contamination (Havelaar2001) and was therefore the organism employed in our study. The outer membrane of a gram-negative bacterium a lipid baiatlayer primarily contains lipopolysaccharides (LPS) and proteins. The LPS molecule extends into the surrounding medium and is anchored to the outer membrane by a lipid moiety known as lipid A (Macler, 2000). Adjacent to lipid A is the 2-keto-3-deoxyoctonlic acid; this molecule links lipid A to the core

*Corresponding author: solomoneluozo2000@yahoo.com
poly saccharide region of the LPS (Coughlin et al., 1983; Macleret al, 2000), which consists of techose, glycol, galactose, and N-acetylglucosamine molecules (Holst, 1996; Madigan, 1997). The outermost part of the LPS envelope is a lengthy sugar chain called the O-poly saccharide or O-antigen, for which the exact size and composition are strain specific (Kannenberg, 2001). The types of proteins that exist on the outer membrane include unique lipoproteins, porins (i.e., OmpC, OmpF, OmpA, and PhoE), diffusion proteins, enzymes, and structural molecules (Nikaido and Vaara, 1985). Portions of these proteinaceous molecules are exposed to the external environment. In addition, many gram-negative cells exude extracellular polymeric substances (EPS), which typically consist of proteins, polysaccharides, and nucleic acids (Omoike and Chorover, 2004). Previous studies have addressed the role of these macromolecules on cell adhesion. Specifically, the adhesive nature of bacteria has been attributed to such features as LPS Abu-Lail, and Camesano, 2003; Flemming et al., 1999; Kannenberg and Carlson, 2001; Walker and Elimelech, 2004; outer membrane proteins (Navarre and Schneewind, 1999; Otto, and Hermansson, 1999), fimbrae (Otto et al., 2001), flagella (Deflau et al., 1990), and EPS (Frank and Belfort, 2003; Tsuena et al., 2003).

MATERIALS AND METHOD

Sample Collection

The method of sample collection was in situ method of sample collection from a point source discharge into a drain at Khana in Rivers State from Niger Delta Environment.

COLUMN EXPERIMENTS

Column experiments were performed to monitor the level of transport of E. coli at different deposit of soil formation.

Experiment Set up

The column was set up; the height is 1 metre of 10mm diameter steel pipe, positioned at vertical level, including a funnel of 30cm size that contains 4 litres of waste water. Each sample level of average of 2000mg/l of waste water containing E. coli was poured inside the column. While the flow was passing through the column, a stop watch was used to monitor the speed level, to determine the level of transport of each sample of aquifer materials. The effluent 1000mg/l from the column were collected and subjected to thorough analysis to determine the level of transport of E. coli in each of the aquifer material, which determines the level of transport to aquiferous zone.

DEVELOPED MODELS FOR STATIONARY PHASE CONDITION

\[
\begin{align*}
C &= \text{Concentration [ML}^{-3}] \\
V &= \text{Velocity [LT}^{-1}] \\
D_A &= \text{Dispersion coefficient dimension less} \\
T &= \text{Time [T]} \\
X &= \text{Distance [L]} \\
\end{align*}
\]

STATIONARY PHASE

\[ V^2 D_{x^2} \frac{\partial c}{\partial x} - Kc(x) \frac{V(x)}{t} = \frac{V\partial c(x)}{\partial t} \quad \ldots \quad (1) \]

If \[ \frac{\partial c}{\partial x} + \frac{V\partial c(x)}{\partial t} \quad \ldots \quad (2) \]

and \[ V^2 D_{x^2} \frac{\partial c}{\partial x} = \beta \]

We have \[ \frac{\partial c(x)}{\partial t} - Kc(x) \frac{V(x)}{t} = \beta \quad \ldots \quad (3) \]

Such that \[ \frac{V\partial c(x)}{\partial t} = Kc(x) \frac{V(x)}{t} - \beta \quad \ldots \quad (4) \]

By transformation of eqn (4) we have \[ C(x) = TX \]

This implies that \[ \frac{\partial c(x)}{\partial x} = T^1 X \]

It can be obtained from separation of variables \[ \frac{\partial c(x)}{\partial x} = TX^1 \]

Substituting into eqn (4) we get

\[ V(T^1 X) = KTX^1 - TX \frac{\partial v(x)}{\partial t} \quad \ldots \quad (5) \]

Expanding further we have

\[ VT^1 X = KTX^1 - TX \frac{\partial v(x)}{\partial t} \quad \ldots \quad (6) \]

Dividing eqn (6) by TX we have

\[ \frac{VT^1 X}{TX} = KTX^1 - TX \frac{\partial v(x)}{\partial t} \quad \ldots \quad (7) \]

This implies that

\[ \frac{VT^1}{T} = KX^1 - \frac{\partial v(x)}{\partial t} \quad \ldots \quad (8) \]

If \[ \frac{V\partial c(x)}{\partial t} = \lambda^2 \]

We have

\[ \frac{VT^1}{T} = \frac{KX^1}{X} - \frac{\partial v(x)}{\partial t} = \lambda^2 \quad \ldots \quad (9) \]

Simplifying it term by term we have

\[ \frac{VT^1}{T} = \lambda^2 \quad \ldots \quad (10) \]

\[ VT^1 - \lambda^2 T \quad \ldots \quad (11) \]

Let \[ T(o) = 0 \]

\[ VT^1 = \lambda^2 T = 0 \]

Considering the boundary conditions we have

\[ T(o) = Ca_1 \quad \ldots \quad (13) \]

Where \( Ca_1 \) is the initial concentration

\[ V(ST(o) - Ca_1) - \lambda^2 T_o = 0 \quad \ldots \quad (12) \]

\[ VST(o) - VCa_1 - \lambda^2 T_o = 0 \quad \ldots \quad (14) \]

or

\[ VST(o) - VCa_1 - \lambda^2 T_o = 0 \quad \ldots \quad (15) \]
\[ VST_{(s)} - \lambda^2 T_{(s)} = C_{a_1} \quad \text{.......... (16)} \]
\[ (VS - \lambda^2)T_{(s)} = C_{a_1} \quad \text{.......... (17)} \]

Then
\[ T_{(s)} = \frac{V C_{a_1}}{V S - \lambda^2} \quad \text{.......... (18)} \]
\[ V S = \lambda^2 = 0 \]
\[ S = \frac{\lambda^2}{V} \quad \text{.......... (19)} \]

Therefore,
\[ T_{(s)} = V C_{a_1} \ell \sqrt{\frac{\lambda^2}{V}} \quad \text{.......... (20)} \]

\[ K \frac{X'^1}{X} = \lambda^2 \]

where
\[ X_{(s)} = C_{a_2} \]

If we have
\[ X_{(s)} = \frac{K X'^1}{X} C_{a_2} \ell^{\frac{\lambda^2}{K C_{a_2}}} \quad \text{.......... (21)} \]

\[ \frac{\partial v(x)}{\partial t} = \lambda^2 \]
\[ S V_{(s)} - V_{(s)} C_{(s)} = \lambda^2 \quad \text{.......... (22)} \]

Integrating the initial concentration for which
\[ V_{(s)} = C_{a_3} \]
\[ S V_{(s)} - C_{a_3} = \lambda^2 \quad \text{.......... (23)} \]
\[ S V_{(s)} = \lambda^2 + C_{a_3} \quad \text{.......... (24)} \]

Making \( V S \) the subject relation gives
\[ V_{(s)} = \frac{\lambda^2 + C_{a_3}}{S} \quad \text{.......... (25)} \]

Using Laplace inverse where we obtained
\[ V_{(t)} = \lambda^2 + C_{s_3} \quad \text{.......... (26)} \]
\[ \lambda^2 = \frac{v t}{C_{a_3}} \quad \text{.......... (27)} \]

\[ \frac{V T'^1}{T} = \frac{K X'^1}{X} - \frac{\partial v(x)}{\partial t} = \lambda^2 \quad \text{.......... (28)} \]

If we let \( C_{(s)} = T X \) we obtain
\[ \frac{V T'^1}{T} = \frac{K X'^1}{X} - \frac{\partial v(x)}{\partial t} \quad \text{.......... (29)} \]

Integrating both sides gives
\[ \frac{V C_{a_1} \ell^{\frac{\lambda^2}{V}}} = K C_{a_2} \ell^{\frac{\lambda^2}{K}} \quad \text{.......... (30)} \]

\[ C_{(s)} = V C_{a_1} \ell^{\frac{\lambda^2}{C_{a_3}}} = K C_{a_2} \ell^{\frac{\lambda^2}{C_{a_2}}} \quad \text{.......... (31)} \]

\[ C_{(s)} = T_{(s)} = T_{(s)} X_{(s)} \]
\[ C_{(s)} = \left( V C_{a_1} \ell^{\frac{\lambda^2}{C_{a_3}}} \right) \left( K \ell^{\frac{\lambda^2}{K}} \right) \quad \text{.......... (32)} \]

Given the constraint below since
\[ t = o, \quad x = C_{(s)} = C_m \]

We have
\[ C_m = C_{a_1} C_{a_2} \quad \text{.......... (33)} \]

Such that
\[ C_{a_1} = \frac{C_m}{C_2} \quad \text{.......... (34)} \]

Integrating through we have
\[ C_{(s)} = \left( V C_m \ell^{\frac{\lambda^2}{C_{a_3}}} \right) \left( K \ell^{\frac{\lambda^2}{K}} \right) \quad \text{.......... (35)} \]

By indices, it simplifies it as
\[ C_{(s)} = V^3 K C_m \ell^{\frac{\lambda^2}{K}} + \lambda^2 \quad \text{.......... (36)} \]

If \( V = \frac{\partial}{\partial t} \) we have
\[ C_{(s)} = \frac{d^3}{t^3} K C_m \ell^{\left( \frac{\lambda^2}{t} + \frac{\lambda^2}{K t} \right)} \quad \text{.......... (37)} \]

\[ C_{(s)} = \frac{d^3}{t^3} K C_m \ell^{\left( \frac{\lambda^2}{t} + \frac{\lambda^2}{K t} \right)} \quad \text{.......... (38)} \]

\[ C_{(s)} = \frac{d^3}{t^3} K C_m \ell^{\left( \frac{\lambda^2}{t} + \frac{\lambda^2}{K t} \right)} \quad \text{.......... (39)} \]
RESULTS AND DISCUSSION

From the figure it shows that the concentration gradually increase with increase in distance in an oscillation form, to an extend where an optimum value were observed at twenty one metres, and suddenly decrease from twenty four to thirty metres.

Table 1. Concentration of E.coli at Various Distance versus time

<table>
<thead>
<tr>
<th>Time</th>
<th>Theoretical model Result Conc. Mg/L(DV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.41E-03</td>
</tr>
<tr>
<td>20</td>
<td>9.60E-04</td>
</tr>
<tr>
<td>30</td>
<td>0.024</td>
</tr>
<tr>
<td>40</td>
<td>0.1</td>
</tr>
<tr>
<td>50</td>
<td>0.41</td>
</tr>
<tr>
<td>60</td>
<td>1.71E-03</td>
</tr>
<tr>
<td>70</td>
<td>0.42</td>
</tr>
<tr>
<td>80</td>
<td>0.023</td>
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<tr>
<td>90</td>
<td>1.00E-14</td>
</tr>
<tr>
<td>100</td>
<td>1.86E-16</td>
</tr>
</tbody>
</table>

Table 2. Concentration of E.coli at Various Distances versus time

<table>
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</tr>
</tbody>
</table>

Table 3. Comparison of theoretical value column experimental Result versus Distance

<table>
<thead>
<tr>
<th>Distance</th>
<th>Exp Result Conc. Mg/l</th>
<th>Theoretical model Result Conc. Mg/L(DV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.00013</td>
<td>1.41E-03</td>
</tr>
<tr>
<td>6</td>
<td>0.00095</td>
<td>9.60E-04</td>
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<tr>
<td>9</td>
<td>0.021</td>
<td>0.024</td>
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<tr>
<td>12</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>15</td>
<td>0.38</td>
<td>0.41</td>
</tr>
<tr>
<td>18</td>
<td>0.00167</td>
<td>1.71E-03</td>
</tr>
<tr>
<td>21</td>
<td>0.39</td>
<td>0.42</td>
</tr>
<tr>
<td>24</td>
<td>0.019</td>
<td>0.023</td>
</tr>
<tr>
<td>27</td>
<td>0.000014</td>
<td>1.00E-14</td>
</tr>
<tr>
<td>30</td>
<td>0.000018</td>
<td>1.86E-16</td>
</tr>
</tbody>
</table>

Table 4. Comparison of theoretical value column experimental Result versus Time

<table>
<thead>
<tr>
<th>Time</th>
<th>Exp Result Conc. Mg/l</th>
<th>Theoretical model Result Conc. Mg/L(DV /SP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.00013</td>
<td>1.41E-03</td>
</tr>
<tr>
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</tbody>
</table>

Fig. 1. Comparison of theoretical value with column experimental Result Versus Distance

This condition can be attributed to the level of deposition of the stratum base on the geological formation deposited in the study area. this also explain the level of deposition with respect to microbes migration influenced by the deposition of the formation at khana deltaic environment, which happen to generate a lots of variation in the concentration of microbes, from the study it is discovered that it varies from one soil formation to the other, the level of its heterogeneity in concentration shows that their migration generates a lots of variation that resulted to more accumulation of microbes in some region where it station, if there is deposition of micronutrients, they increase in microbial population. The stationary conditions of microbial transport contribute more to ground water pollution. It produces the best fit line equation displayed on the graph.

Fig. 2. Comparison of theoretical value with column experimental Result Versus Distance

From the figure presented the concentration of e.coli gradually increase in vacillation form to a point where an optimum value were recorded at seventy days, a sudden decrease was observe from eight days to hundred days, this prove that the migration of the microbes duration varies, it also explain that the ability of migrating fast to ground water aquifers are determined from the lithology from the study area, the issue of stationary condition depend mostly on the soil matrix and deposition of other microelement, the study area were confirm to generate these type of deposition, therefore the behaviour of e.coli considering stationary phase, become imperative to generate a solution that will solve this type of pollution generating from microbes, the method considered were integrated into the system in formulating a model, it generated the result presented in the figure with best fit equation displayed on the graph.
Figure 3, the figure presented, shows that the concentration of the microbe increase with distance, until an optimum value was obtained, at a distance range of twelve metres. Similarly, a sudden decrease in concentration of the microbes was observed with increase in distance and the behaviour in the concentration of the microbes is in wave form as presented in figure, similarly to experimental result in the same vein it maintained the same form of concentration, but with little increase in optimum value its was achieved at fifteen metres decreasing in fluctuation form down to thirty metres, at this condition, it implies that both concentration can be attributed to the following reason change in distance, and decrease in microbial population, porosity and other environmental factors.

![Fig. 3. The comparison of theoretical model with experimental result of column stationary phase versus Time.](image)

The figure presented shows that the concentration with respect to time from both results, displayed its optimum value at forty days for experimental result and fifty days for theoretical result, but the optimum value of the experiment was higher, the model comparison fit in with the experimental result. This shows that the model can be applied in some study area where is confirm that the migration of microbes e.coli are seen to have such behaviour through the level of concentration. The results of both parameters display the best fit line equation $Y = 2E-11x^2 - 5E-09x^3 + 6E-07x^4 - 4E-05x^5 + 0.001x^2 - 0.038x + 0.231$ with its Root of $(R^2 = 0.418)$.

**Conclusion**

The Study have explain a lots of reason why it is imperative to carry a thorough research, considering the transport of E.coli in stationary phase condition, the variation of the microbial transport to ground water aquifer were confirm to be very high in some distance and time, which has generated a rapid increase in pollution transport of e.coli at khana in Rivers state, this has generated lots of water related diseases of which most settlers in those area do not know their sources of ill health, the level of death trap from e.coli transport to ground water aquifers in the study area is of serious concern, and call for urgent attention, the model formulated with theoretical value result were compared, the model value fit in with the experimental result which implies that the model can be applied in any detail environment as benchmark for solving ground water pollution considering stationary phase condition.

**REFERENCE**


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