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ASSESSMENT OF GROUNDWATER QUALITY AND CHARACTERISTICS FORMATION IN PHREATIC AQUIFERS IN AHOADA WEST L.G.A, RIVERS STATE, NIGERIA

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ABSTRACT

The research was to find a better solution to pollution transport in groundwater, considering the effect of geologic parameters such as heavy metals, micronutrients, porosity, permeability, and void ratio. The source of pollution was through indiscriminate dumping of biological wastes and wastes from soakaway, regenerating the wastes in most parts of the study area. This research was carried out through an experiment performed for E. coli transport, including some other parameters that influence microbial growth, inhibition and variation for fast migration within a short period of time. These parameters are heavy metals, micronutrients, permeability, porosity, and void ratio. The physiochemical parameter from the study carried out found that the growth of E. coli under environmental conditions favoured it. The research was able to produce the level of physiochemical parameters influencing E. coli concentration in groundwater. The presence of E. coli depends on the availability of nutrients as well as favourable conditions in terms of physicochemical parameters. The study confirmed that the higher the depth of water, the lower the population of E. coli in some locations based on the decrease in substrate utilization; while in some areas, it varies. The study carried out was able to express the stabilization of groundwater quality by inhibiting the presence of metallic element in some locations; while in a few locations in the study area, it was discovered that the presence of E. coli in different aquifers have a lower percentage and become less harmful to the quality of groundwater for human utilization. The level of porosity was investigated on the migration of E. coli influenced by porosity from one aquifer to the other, the results were calibrated and verified generating a model that can be applied to predict the rate at which E. coli transport within a short period of time.

KeyWords
Groundwater, Water Quality, Phreatic Aquifer, E. coli, Transport Mechanism, Ahoada West L.G.A., Rivers State

1.0 Introduction

The quality and quantity of water valuable to humans have disappeared due to water shortages resulting from changes in climate. Even temperature, fluctuation, and limited precipitation caused problems. It covers three-quarters of the world and settlement hinges on the provision of water. Worldwide, quite one billion people don't have access to wash water.
Groundwater is the water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations (Alagbe, 2010, Alagbe et al. 2013). About thirty percent of groundwater consists of H_2O, most of which is inaccessible, unusable or could also be obtainable at the nice expense of energy. Only three-tenth of one percent of total freshwater may be truly considered renewable. Conversely, unconfined flow occurs where there's a transition flow, positive fluid pressures within the saturated a part of the domain, across an interface called the phreatic surface where the fluid pressure is atmospheric, into the unsaturated zone where fluid pressures are negative due to capillary forces.

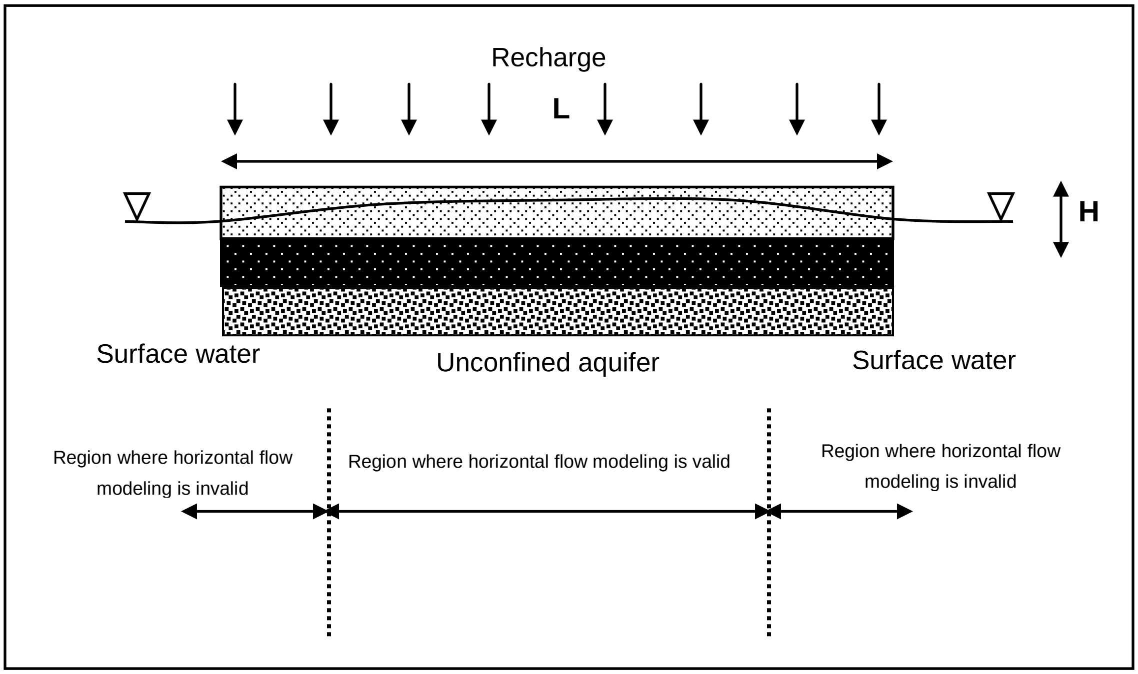

Figure 1.1: Unconfined groundwater flow and associated processes at the regional scale.

Hence, there is an open continuum, between surface processes, both natural (e.g. recharge) and artificial (e.g. waste disposal), and subsurface flow processes under unconfined conditions, then it's imperative that unconfined flow processes will be quantified to help within the understanding and management of stresses upon the resource.

The fluvial has marine deposits that include clay upward changing to laminated clay silt and fine sand. The fluvial-marine transition gradually becomes more pronounced, the sand thickens, the grain size increase and the plant remain become more prominent. Figure 1.1., shows a schematic diagram of an unconfined aquifer and associated features such as the phreatic surface and recharge processes. This implies that there will be variations in the stratigraphy in the study area and will definitely influence the transport base on these conditions. The deposited formation was confirmed to be the highest yield formation from a phreatic aquifer deposited, in every part of Rivers State, predominantly 90% of sandstone and 5% of sandstone and sedimentary deposited, it also has a predominant Montmorillonite clay mineral including some other locations of deposited some hazardous chemical from manmade activities and natural origin. Its water table based on the study has an average of 7.5m water table. But in most coastal environments, it has an average of 1.5m water table. The study also found that a rich aquiferous zone has an average depth of 30-36 meters in the highland area and 12-15 meters in the coastal area. Because of the high level of variation in depth of formation for quality water, the porosity of the soil was confirmed to be very high, making the focus of the study imperative for pollution transport. Abstraction of good quality groundwater is complex due to the high level of variation in depth of formation for quality water. However, some deposited physiochemical parameters are also confirmed to be deposited on some parts of Rivers state, the deposition has the man-made activities influence including the natural origin. Thus, in general, aquifer passage reduces pathogenic microorganism concentration and numerous successes have been reported in cases like artificial recharge schemes or riverbank filtration projects, where microorganisms were completely removed. In Rivers State this is a serious problem; over sixty per cent of the water abstracted from the ground is polluted water, because of inadequate implementation of design and application of standards in other to prevent these pollution threats to human life.

However, studies in the United States have found that up to half of all drinking water wells tested contained signs of faecal pollution, and that contaminated groundwater might cause 750,000 to 5.9 million illnesses and 1400-9400 fatalities every year. (Eluozo & Nwaoburu, 2013).

Certainly, E. coli is one of the major bacteria that play a major role in all the subject areas associated with the environment e.g. soil, air, and water. Many waterborne diseases are caused by pathogenic bacteria, and it is the major task of water treatment. Bacteria like E. coli, which normally live in the intestine of warm-blooded animals and are excreted with faces, are used as indicator bacteria. If present in a water sample, they indicate that contamination of water has taken place, and thus the potential presence of pathogenic exists. E. coli is the parameter tested, as an indicator of the presence of faecal bacteria and perhaps viruses which pose a significant risk to human health.

The most common health problem arising from the presence of faecal bacteria in groundwater is diarrhoea, but typhoid fever, infectious hepatitis and gastrointestinal infections can also occur (Cronin, et. al., 1999).

Although E. coli bacteria are an excellent indicator of pollution, they can come from different sources e.g. septic tank effluence, farmyard waste, and landfill sites. The published data about the elimination of bacteria and viruses in groundwater has been compiled by experts who show that in different investigations, 99.9 percent elimination of E. coli occurred after 16 to 120 days with a mean of

35 days for polio-hepatitis and entero-viruses. The natural environment, in particular, the soil and subsoil are effective in moving bacteria and viruses by predicting filtration and absorption.

The aim of this study is to analyze the values used to describe and quantify the attachment and inactivation of E. coli during transport in aquifers under saturated conditions, with the aim of elucidating the relative importance of the various factors influencing the transport mechanism (Foppen & Schijven, 2006).

2.0 Material and Methods

2.1 The Study Area

The study area is Akinima community in Ahoada West Local Government Area in Rivers State, Nigeria (Fig. 2.1) along the Sombrero River. The Sombrero River is located between latitude 6°30′ and 7°0′ E, and longitude 41°21 N and 60°17 N. Ahoada L.G.A. It lies between longitude 6°28′E and 6°30′E and latitude 5°5′N and 5°10′N of the equator. It is bounded in the North by Joinkarama community, in the south by Oruama community, in the west by Okordia, and Zarama communities and to the east by the river Orashi. (Nnodu, et. al., 2010). It has a topography of flat plains in a network of rivers - the Niger, Sambreiro, Orashi and other tributaries along with a network of creeks (Abowei, et. al., 2008, Umunnakwe & Aharanwa, 2016). The study focuses on the Benin formation i.e. groundwater disintegrating to the Sombrero river that transit at the Ahoada River, the geologic history of Rivers State is predominated by the deposited formation.

The stratigraphy of the study area is deposited by lacustrine, Alluvial and fluvial including off-lap sediments, the lacustrine deposit in the study area is heterogeneous predominant while alluvial and fluvial deposits are homogenous predominant. Its coastal area in the study is where off-lap sediments including tidal channels of 60ft and 800ft deep.

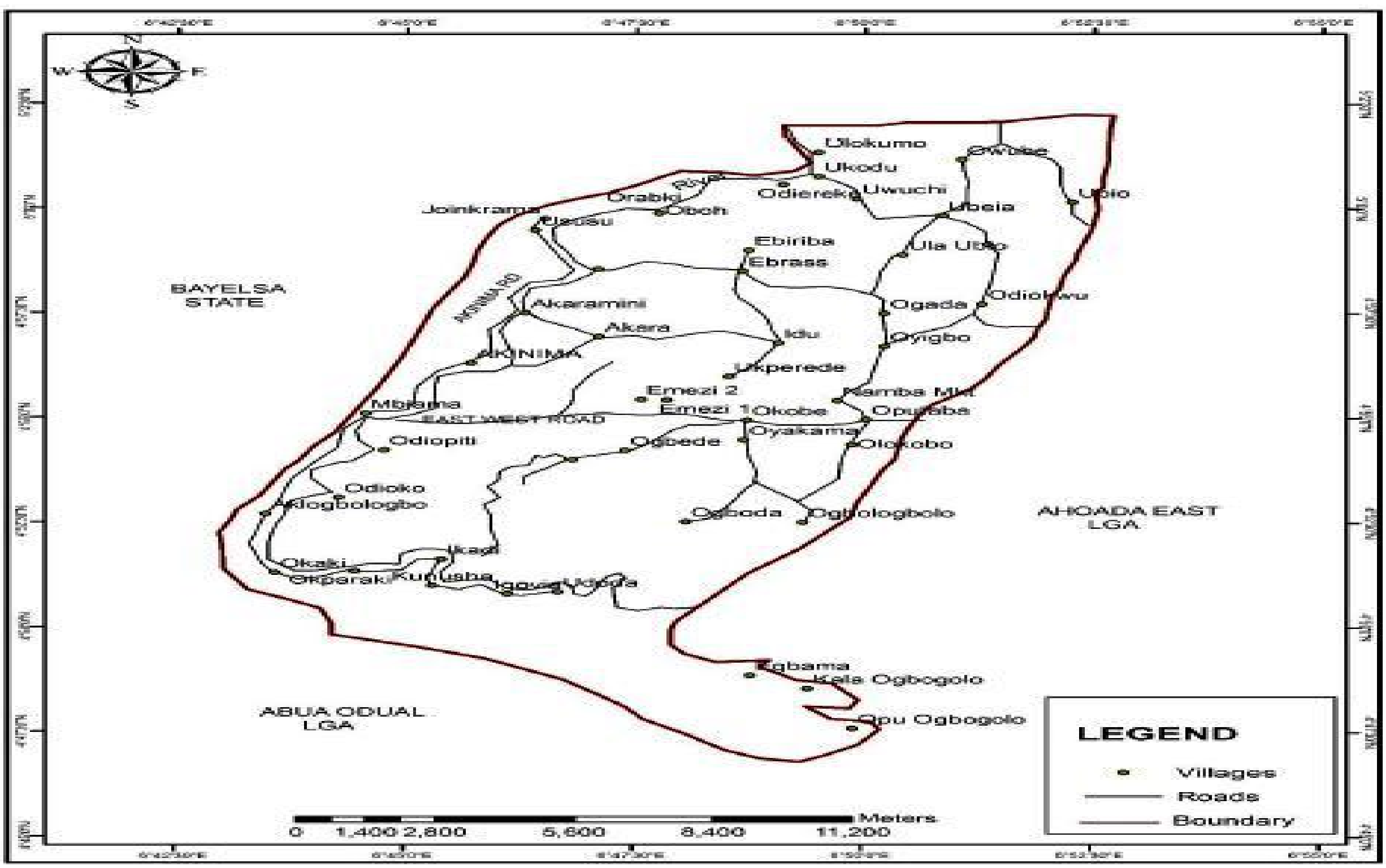

Figure 2.1. Location Map of the Study Area
Source: (Umunnakwe & Aharanwa, 2016).

2.2 Morphology and surface characteristics of *E. coli* Taxonomy

E. coli is a gram-negative, facultative anaerobic, straight, rod-shaped bacterium of 2.0-6.0 µm x l.1-1.5 µm occurring singly or in pairs (Bergey *et al*., 1984) and is a taxonomically well-defined member of the family Enterobacteriaceae. Thermotolerant coliforms are defined as the group of coliforms that are able to ferment lactose at 44-45°C. They comprise the genus *Escherichia* and, to a lesser extent, species of Klebsiella, Enterobacter, and Citrobacter. (Payment, et. al., 2003). Of these organisms, only *E. coli* is considered to be specifically of fecal origin (Medema *et al*., 2003). Thermotolerant coliform are frequently reported as fecal coliform. However, this term is not correct (Payment *et al*., 2003), because not all thermotolerant coliform may be of fecal origin: thermotolerant coliform other than *E. coli* may originate from organically enriched water such as industrial effluents or from decaying plant materials and soils.

Most members of the *E. coli* species are considered to be harmless organisms, while some strains are responsible for illness. Three general clinical syndromes can result from infection with pathotypes: enteric/diarrheal disease, urinary tract infections, and sepsis/meningitis (Kaper *et al*., 2004). Pathogenic strains have been categorized into six groups, based on serological and virulence characteristics (Kaper *et al*., 2004; AWWA, 1999). Perhaps the most well-known pathogenic *E. coli* is the serotype O157:H7 of the enterohemorrhagic *E. coli* (EHEC) group (Foppen & Schijven, 2006).

2.3 The Surface of E. coli

Bacterial attachment to surfaces is influenced by cell surface charge, Hydrophobicity, size, and the presence of particular surface structures such as flagella, fimbriae, and extracellular lipopolysaccharides (Gilbert et al., 1991). Because of their physical location on the outside of E. coli, lipopolysaccharides (LPSs) are believed to be a key factor in the attachment of microbes to mineral surfaces, the uptake of metal ions, and microbial-induced precipitation/dissolution reactions. The LPS of E. coli (Amor et al., 2000) consists of (i) a hydrophobic lipid a component anchored in the outer membrane, (ii) a phosphorylated, no repetitive hetero-oligosaccharide known as the core oligosaccharide, and (iii) a polysaccharide that extends from the cell surface and forms the 0-antigen detected in serotyping. Smooth LPS molecules found in most clinical isolates of E. coli are composed of this three-part structure, whereas rough LPS lacks the O antigen and can have a truncated core OS (Kastowksy et al., 1991; Walker et al., 2004). The extent and structural diversity of LPS molecules in E. coli range from the highly conserved lipid A to the extreme variations reflected in more than 170 known 0 antigens (Hull, 1997). The core OS is conceptually divided into inner and outer core regions. Amor, et. al., 2000). The inner core is composed primarily of L-glycero-o-manno-heptose (heptose) and 3-deoxy-D-manno-oct- 2-ulosonic (or 2-keto-3-deoxyoctulasonic) acid (KDO) residues; this part of the core oligosaccharide is phosphorylated in E. coli. Most of the charge on the LPS is concentrated in these phosphate groups of the inner core, and to a lesser extent on carboxylic acid groups of KDO (Kastowksy et al., 1991). The molecular interactions of these bacterial surface functional groups control attachment to surfaces. In these studies (factors affecting the collision efficiency), from previous researchers, more attention was paid to the influence of LPS structure on the transport of E. coli in aquifers.

2.4 *E. coli* in Water

When E. coli bacteria are introduced into water environments, they gradually die and this process is accompanied by changes in their characteristics. Daubner (1975) carried out survival experiments using E. coli strains freshly isolated from the excreta of healthy persons in sterile demineralized water, Danube water, is highly mineralized water. Previous research monitored the morphological and physiological properties of E. coli during die-off. Five to twenty hours after E. coli had been transferred to the sterile water, shrinking of the cell and the reduction of cytoplasmatic content (distilled and Danube water) or damage to the integrity of the cell (mineralized medium) was observed. Kerr et al. (1999) also observed widespread damage to the majority of cells of E. coli 0157: H7, with large spaces between the cell wall and the cell membrane. In addition, Daubner (1975) observed changes in the biochemical activity of the cells, the most important ones being an immediate decrease in respiration and dehydrogenase activity of the cells when introduced into the water environments. Another important biochemical activity change was the utilization of citrate as a sole carbon source. During the survival of E. coli STCC 416 under adverse conditions, Arana et al. (2004) observed the release of proteins, dissolved free amino acids, and dissolved monomeric carbohydrates into the surrounding medium and the transition from the culturable state to the viable but non-culturable (VBNC) state. In the VBNC state, E. coli cells maintain their integrity and some metabolic activity, but they lose the ability to grow in culture media (Barcina et al., 1997).

2.5 Relative Importance of the Bacteria Transport Mechanisms

At Darcy groundwater velocities between 0.1 and $10md^{-1}$ and a grain size of 1 mm, the diffusion and sedimentation components are the dominant bacterial transport mechanisms When Darcy flow velocity increases, the diffusion and sedimentation components decrease, and Interception and straining remain unaltered. When the grain size decreases to 0.02 mm (the approximate boundary grain size value between silt and clay; then diffusion, interception, and straining are the dominant transport mechanisms. Sedimentation does not depend on grain size and remains unaltered.

2.6 Effect of grain size uniformity of sediment

The uniformity of the sediment is defined as (Matthess *et al*., 1991a)

$$U = \frac{a_c,60}{a_c,10} \tag{2.1}$$

Where the numbers 10 and 60 refer to the 10^{th} and 60^{th} percentile values of the log-normal grain size number distribution curve. Matthess *et al*. (1991a) prepared a number of sediment mixtures in such a way that the median of the grain size number distribution curve did not vary (it was taken at 0.45 mm). The results demonstrated that the uniformity, *U*, did not significantly influence the filter coefficient of *E. coli*. While *U* increased from 1.71 to 9.98, the filter coefficient hardly changed.
We agree with the conclusions reached by Matthess *et al*., (1991a) and Matthess *et al*., (199lb) after their experiments, that measured filter coefficients and calculated filter coefficients determined with the SCCE (determined with the TE correction equation), neglecting straining and one sticking efficiency value of 0.43, were in reasonable agreement. This demonstrates the usefulness of colloid filtration theory for predicting the transport of bacteria in porous media under saturated conditions.

2.7 Permeability Test

Falling-head test method is the method applied. This method is usually employed to determine a coefficient of permeability for fine grain soil. The soil sample is usually undisturbed and very often the U4 sampling tube can be used as container during the test. A coarse filter screen is placed at the upper and lower ends of the sample tube. The base of the sample tube is connected to the water reservoir, to the top of the sample tube is connected a glass stand pipe of known cross section area. This pipe is filled with water as the water seeps down through the soil sample; observations are taken of time versus height of water in the standpipe above base reservoir level. Series of tests are performed, using different sizes of stand pipe and the average value of the coefficient of permeability is taken. Note must be taken of the unit of weight of the sample's moisture content.

2.8 Column Experiments

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

2.9 Bacteriological Testing of Water.

A 100ml water sample was filtered through membrane filters. The membranes, with the coliform organism (*E. coli*) on it, are then cultured on a pad of sterile selective broth containing lactose and an indicator. After incubation, the number of colonies of coliform (*E. coli*) were counted. This gives the presumptive number of *E. coli* in the 100ml water sample.

3.0 Results and Discussion

3.1 Data Analysis

Polynomial expression was generated from all the results in the study area this is one the expression of polynomial applied for porosity, as shown; other parameters generated its models through this polynomial application as expressed below.

$$\begin{bmatrix} n & \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \sum x_i^5 \\ \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \sum x_i^6 \end{bmatrix} \begin{vmatrix} a_o \\ a_1 \\ a_2 \\ a_3 \end{vmatrix} = \begin{vmatrix} \sum y_i \\ \sum y_i x_i^2 \\ \sum y_i x_i^3 \\ \sum y_i x_i^4 \end{vmatrix} \quad (2.2)$$

Table 3.1: location 1 data

X DEPTH (M)	Y POROSITY (N)
3	0.84
6	0.58
9	0.46
12	0.74
15	0.46
18	0.3
21	0.12
24	0.04
27	0.04
30	0.01

Third degree polynomial fitting,

$$y = a_o + a_1 x + a_2 x^2 + a_3 x^3 \quad (2.3)$$

The elements of the matrix are obtained using the table below for the location1 data above.

Table 3.2: Elements of Matrix Table for location 1 data

S/No	x	y	x^2	x^3	x^4	x^5	x^6	yx	yx^2	yx^3
1	3	0.84	9	27	81	243	729	2.52	7.56	22.68
2	6	0.58	36	216	1296	7776	46656	3.48	20.88	125.28
3	9	0.46	81	729	6561	59049	531441	4.14	37.26	335.34
4	12	0.74	144	1728	20736	248832	2985984	8.88	106.56	1278.72
5	15	0.46	225	3375	50625	759375	11390625	6.9	103.5	1552.5
6	18	0.3	324	5832	104976	1889568	34012224	5.4	97.2	1749.6
7	21	0.12	441	9261	194481	4084101	85766121	2.52	52.92	1111.32
8	24	0.04	576	13824	331776	7962624	191102976	0.96	23.04	552.96
9	27	0.04	729	19683	531441	14348907	387420489	1.08	29.16	787.32
10	30	0.01	900	27000	810000	24300000	729000000	0.3	9	270
∑	**165**	**3.59**	**3465**	**81675**	**2051973**	**53660475**	**1442257245**	**36.18**	**487.08**	**7785.72**

The Final matrix equation for fitting by substituting the values of the elements from the table above is thus:

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$$\begin{vmatrix} 10 & 165 & 3465 & 81675 \\ 165 & 3465 & 81675 & 2051973 \\ 3465 & 81675 & 2051973 & 53660475 \\ 81675 & 2051973 & 53660475 & 1442257245 \end{vmatrix} \begin{vmatrix} a_o \\ a_1 \\ a_2 \\ a_3 \end{vmatrix} = \begin{vmatrix} 3.59 \\ 36.18 \\ 487.08 \\ 7785.7 \end{vmatrix} \quad (2.4)$$

From the matrix equation above, the values of the constants can be found using a matrix solver. Substituting the values into equation (2.1) to get the appropriate polynomial fit. Other results were generated using excel programme.

3.2 The Flow Diagram

The flow diagram is the true representation of geological formation in the study area, the diagram express variation in the study locations including some type of soil that are predominant in the study location.

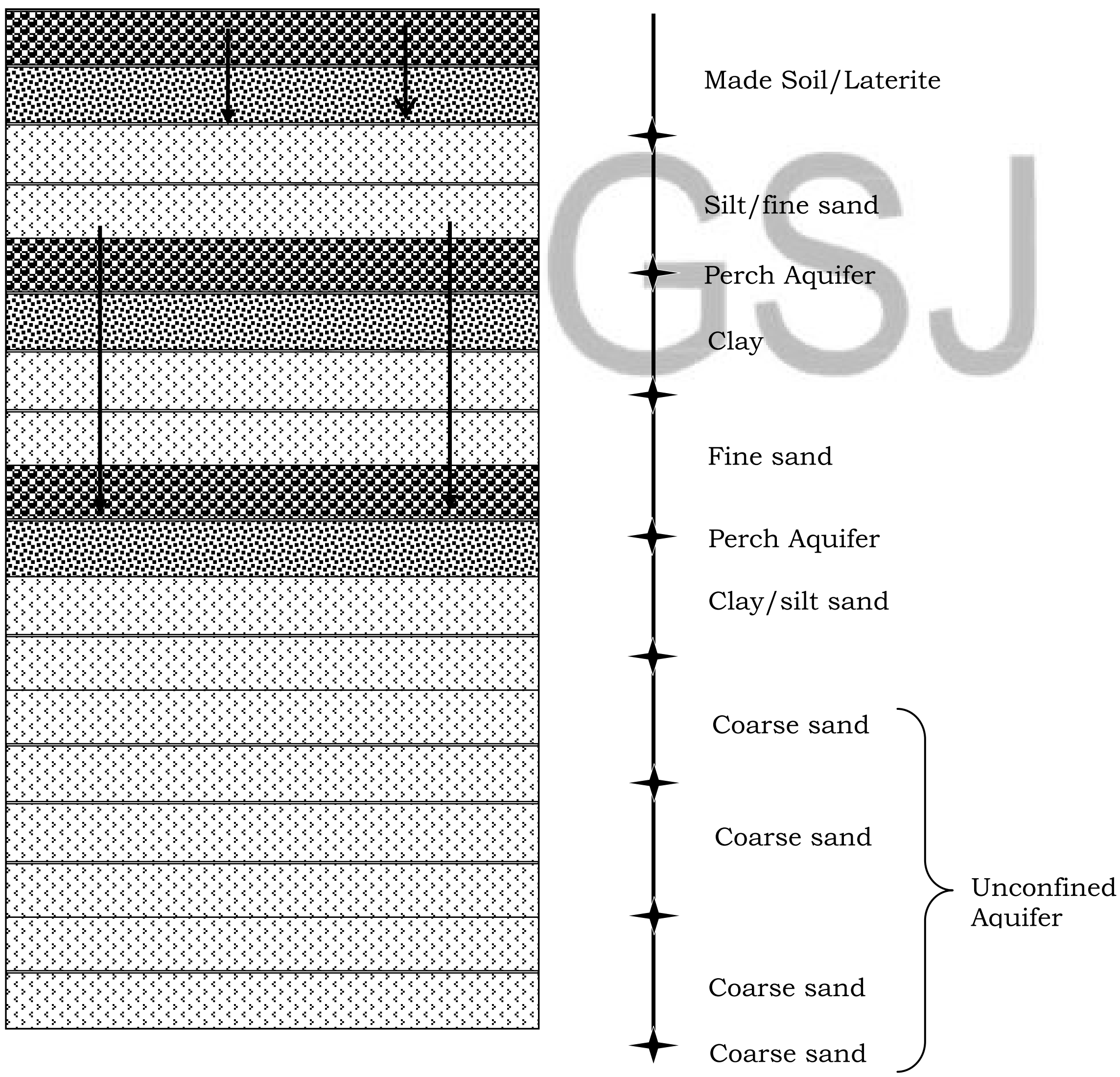

Figure 3.1: Flow diagram of soil formation in the study area.

Figure 3.1 above shows an experimental zone process taking place as investigated. The tables from all the experiments performed including the results from the empirical model applied to verify the results through polynomial expressed equations.

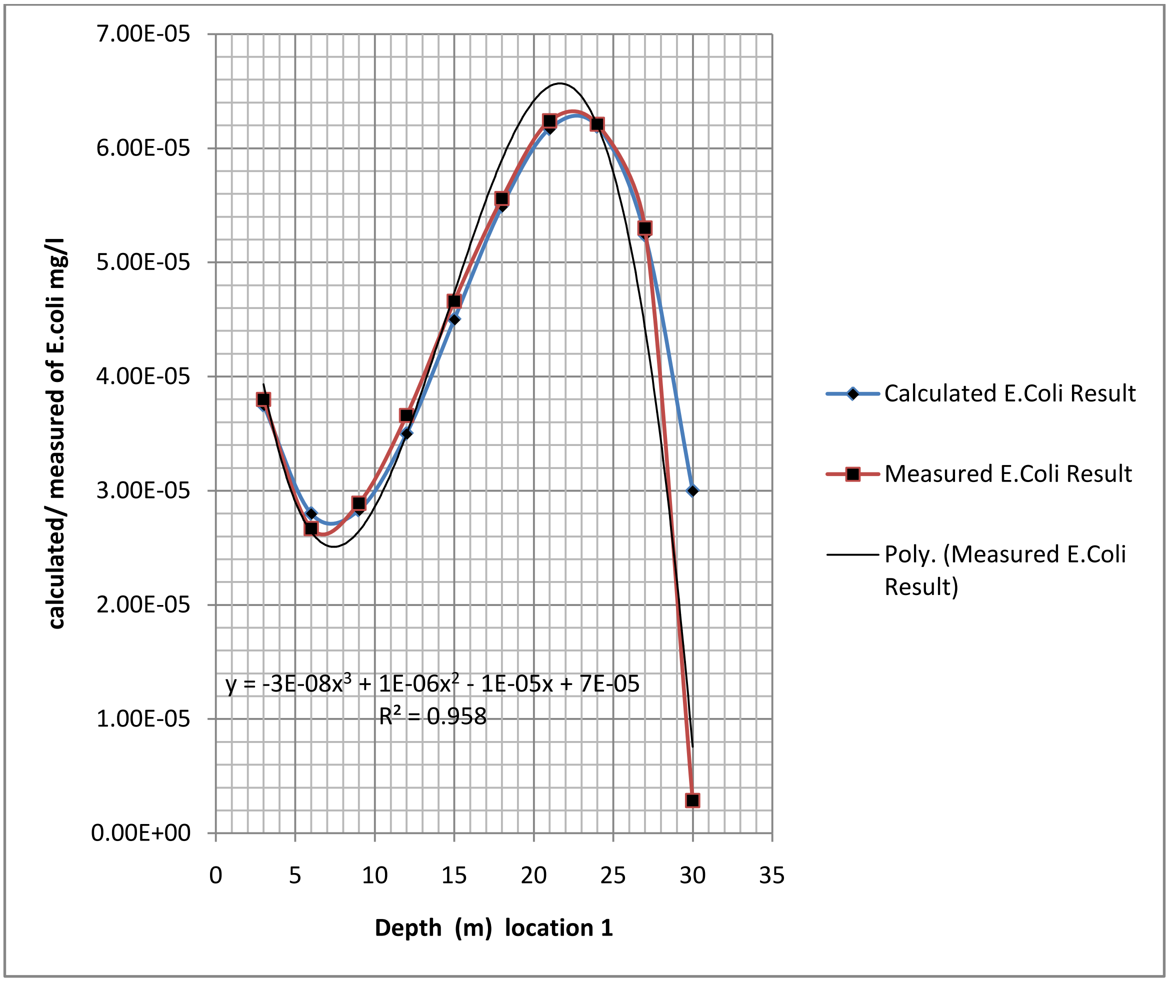

Figure 3.2: Calculated and Measured values for E. coli transport at different depths

In Figure 3.2, from the result the calculated E.coli concentration increased with depth in fluctuation form to a point where an optimum value was recorded at twenty one metres and suddenly decrease with distance, while that of the measured maintained the same level of concentration, but the measured generated a higher concentration more than the calculated value, this concentration can be attributed to change in deposition of the formation, as well as variation in concentration of the microbes in the stratum, the both parameters fit in as they explain the level of verification. The best fit line equations are displayed on the graph.

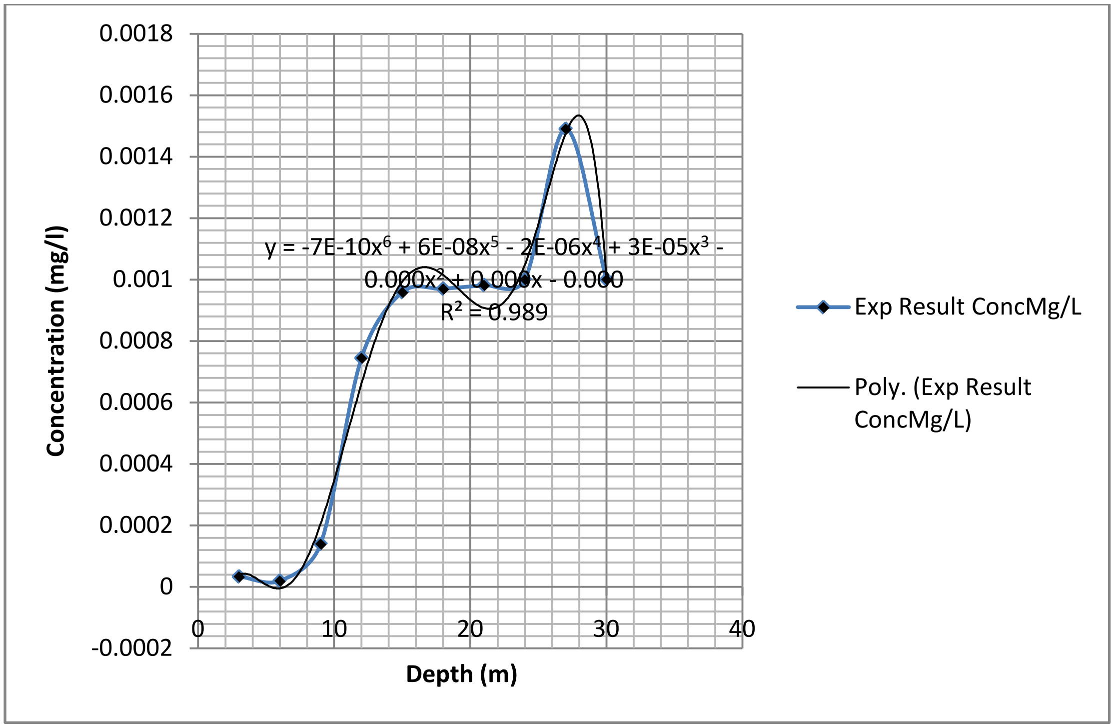

Figure 3.3: Concentration of column E. coli at different Depths

In Figure 3.3, the concentration rapidly increased in a vacillation form and obtained its optimum value at twenty-seven metres, finally dropped a little, this can be attributed to change in soil stratum caused by other depositions either by manmade activities or natural origin, these two conditions can cause the concentration of the microbes deposited in this form as presented in figure. Furthermore, looking at this condition, quality ground water can be abstracted from this formation, but will be subjected to thorough treatment before it can be allowed for human consumption. The best fit line equations are displayed on the graph.

4.0 Conclusion

Investigation into transport of E. coli in phreatic aquifer was carried out and the findings are presented as follows:

- The presence of E. coli on any aquifer depends on the availability of the nutrient as well as faviourable condition in terms of physiochemical parameter.
- The concentration of E. coli increases with reduction of nutrient, because at the formation the nutrient generated high level of deposition, the microbes definitely remain at that formation and con-

tinue to feed at that region, they will definitely decrease the concentration of the nutrients, this will result to the microorganism increasing rapidly in growth rate.

- Rapid growth rate on the population of E. coli is experienced when the pH value is acidic than alkaline, therefore the influence of these depositions determines the level of population.

- The E. coli helps to stabilize groundwater quality by inhibiting the presence of metallic element, in most cases; the microorganism reduced the level of concentration on metallic element deposited in some location in the study area.

- The presence of E. coli at different aquifer in this condition is less harmful to the quality of groundwater, for purpose of human utilization.

- Investigation on this microbial transport E. coli on groundwater aquifer has generated a lot of challenges; the investigation carried out has generated a better solution that will definitely improve the condition of groundwater quality in Rivers State.

- Another concept that is applied which has generated better solution to solve microbial transport is calibration and verification of permeability to determine the level influence from those parameters those verified model that can be used to monitor and predict the microbial growth rate of E. coli in different aquifers.

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