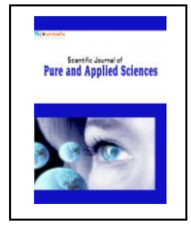
Sjournals
Scientific Journals
Scientific Journal of Pure and Applied Sciences (2013) 2(3) 151-160
ISSN 2322-2956

Contents lists available at Sjournals
Scientific Journal of
Pure and Applied Sciences
Journal homepage: www.Sjournals.com



Original article

Model prediction to monitor the influence of porosity effect on Shigella transport to ground water aquifers in Elele rivers states of Nigeria

S.N. Eluozo
Subaka Nigeria Limited Port Harcourt Rivers State of Nigeria.

*Corresponding author; Subaka Nigeria Limited Port Harcourt Rivers State of Nigeria.

A R T I C L E I N F O

Article history:
Received 07 February 2012
Accepted 27 February 2013
Available online 30 March 2013

Keywords:
Model prediction
Transport
Water

A B S T R A C T

Model prediction to monitor the influence of porosity effect on shigella transport to ground water aquifers has been examined, the model where generated from a mathematical equation from an experimental values, the model equation from an excel plot where resolved to produced a theoretical values, the application of least square method where applied to resolved polynomial generated equations, the theoretical values where compared with other experimental values from different locations, both parameters developed a valuable fit. this implies that the model can be applied to determine that degree of porosity in various formation, high porosity rate where found to influence the degree of shigella concentration, this is confirmed through the deposited degree of porosity at different formations, high degree of hydraulic conductivity where experienced in the study location, base on the deposition of high degree of porosity recorded between 0.2 to 5m, although some proof to be very low, but it can not be compared when the depth increased to homogenous fine and coarse formation. The model will definitely be a benchmark to monitor degree of porosity that reflects on the transport of shigella to ground water aquifers in the study area.

1. Introduction

In many parts of sub-Saharan Africa, hydrogeologic data are sparse and difficult to access. One example is the Nigeria geological formations including other countries geological history like Keta Basin of southeastern Ghana and the Coastal Sedimentary Basin of Togo. Existing data quality on groundwater flow patterns and hydrodynamic aquifer characteristics from this region is weak, and subsurface geology is poorly understood in many parts of the region. In the present study, hydrochemistry and isotope geochemistry are applied to obtain hydrogeological information from the area in spite of lack of basic data on groundwater flow patterns and aquifer characteristics (Tina, 2006).

In regard to permeability predictions, Koltermann and Gorelick (1995) modified the Kozeny-Carman equation to better represent sediment mixtures by incorporating their fractional packing model for porosity. Kamann (2004) measured porosity and permeability on sediment mixtures and then compared these to values predicted by the models mentioned above. These mixtures were model approximations of natural poorly-sorted sands and sandy gravels. The introduction of five possible types of packing that can occur in a sediment mixture accounts for complex packing arrangements that may be present naturally. Therefore,

Kamann (2004) assumed that the expanded fractional packing model is generally representative of poorly-sorted sands and sandy gravels. The present study will evaluate how well the model applies to natural sediment. Taking the results and procedures of Kamann (2004) into account, Conrad (2006) focused further on the permeability of bimodal sediment mixtures by taking measurements at small support scales. Conrad (2006) revised the air-based permeability procedures of Kamann (2004) to reduce displacement of sediment by air slip-flow. Conrad (2006) determined a sufficient depth in the sediment at which a stable representative measurement could be taken, which he termed the tip-seal burial method. He also improved upon the correction needed for the air-based measurements to account for the effects of high-velocity flow. He repeated the permeability measurements taken by Kamann (2004) and further confirmed the applicability of the permeability model. Conrad (2006) found that the air-based measurements corresponded well to the water-based measurements for both sand mixtures and sand/pebble mixtures. Thus, the air-based measurements with a small support scale were generally similar to the water based measurements with a larger support scale. Conrad (2006) concluded that the permeability of bimodal sediment mixtures of poorly-sorted sands can be accurately measured with the air-based permeameter. He found that mixtures dominated by finer grains show only subtle differences between air- and water-based measurements. Conrad (2006) determined that the air-based permeameter captures subtle changes in poorly sorted sands better than in pebbly sands. In addition to Kamann (2004) and Conrad (2006), studies have been conducted since the work of Koltermann and Gorelick (1995) that utilize models for predicting permeability. Revil and Cathles (1999) presented a permeability model for bimodal sediment mixtures that is based on parameters that separate pore throat porosity from total porosity and the effective radius from the total radius of the grains. Boadu (2000), developed permeability model using representations of the grain size distribution as well as the petrophysical properties of porosity, volume fraction of fines, and bulk density. Other research on the porosity-permeability relationship for porous media involved the modification of previous models (Barr (2001), Revil et al. (2002), Chapuis and Aubertin (2003), Chapuis (2004), and Costa (2006)). These studies all use different models for predicting permeability but none of them utilize a fractional packing model for porosity. Model sediment mixtures and predicted porosity values are useful tools for testing the applicability of a permeability model. Therefore, the research conducted by Kamann (2004) provides results that can be applied to other permeability models. This study will take the necessary step of testing his model to determine if it is accurate for natural sediment, which will help improve confidence in its applicability (Peter, 2005).

2. Theoretical background

Theoretical background for 3rd degree polynomial curve fitting

General: $y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + ... + a_n x^n$

If the above polynomial fits the pair of data (x, y) it means that every pair of data will satisfy the equation (polynomial).

Thus; $y_1 = a_0 + a_1 x_1 + a_2 x_1^2 + a_3 x_1^3 + \ldots\ldots\ldots + a_n x_1^n$ ………… (1)

$$y_2 = a_0 + a_1 x_2 + a_2 x_2^2 + a_3 x_2^2 + \ldots\ldots\ldots + a_n x_2^n \ldots \qquad \ldots\ldots\ldots\ldots \quad (2)$$

$$y_3 = a_0 + a_1 x_3 + a_2 x_3^2 + a_3 x_2^2 + \ldots\ldots\ldots + a_n x_2^n \qquad \ldots\ldots\ldots\ldots \quad (3)$$

$$y_4 = a_0 + a_1 x_4 + a_2 x_n^2 + a_3 x_n^2 + \ldots\ldots\ldots + a_n x_4^n \qquad \ldots\ldots\ldots\ldots \quad (4)$$

Summing all the equations will yield (1 n) →

$$\sum_{i=1}^{i=n} y_i = \sum a_0 + \sum_{i=1}^{i=n} a_1 x_i + \sum_{i=1}^{i=n} a_2 x_i^2 + \sum_{i=1}^{i=n} a_3 x_i^3 + \sum_{i=1}^{i=n} a_4 x_i^4 + \ldots\ldots + \sum_{i=1}^{i=n} a_n x_i^n$$

$$\boxed{\sum_{i=1}^{i=n} y_i = na_0 + a_1 \sum_{i=1}^{n} x_i + a_2 \sum_{i=1}^{n} x_i^2 + a_3 \sum_{i=1}^{n} x_i^3 + \ldots\ldots + \sum_{i=1}^{n} x_i^n} \qquad \ldots\ldots\ldots\ldots \quad (5)$$

To form the equations to solve for the constants $a_0, a_1, a_2, a_3, \ldots\ldots . a_n$.

We multiply equations (3.84) by $x_{i,} x_i^2, x_i^3 \ldots\ldots\ldots x_i^n$.

$$\sum_{i=1}^{1} y_i = na_0 + a_1 \sum x_i + a_2 \sum x_i^2 + a_3 \sum x_i^3 + \ldots\ldots + a_n \sum x_i^n \qquad \ldots\ldots\ldots \quad (6)$$

Multiply equation (6) by x_i

$$x_i \sum y_i = na_0 x_i + a_1 x_i \sum x_i + a_2 x_i \sum x_i^2 + a_3 x_i \sum x_1^3 + \ldots\ldots\ldots + a_n x_i \sum x_i^n$$

$$\sum y_i x_i = a_0 \sum x_i + a_1 \sum x_i^2 + a_2 \sum x_i^3 + a_3 \sum x_i^4 + \ldots\ldots\ldots + a_n \sum x_i^{n+1} \qquad \ldots\ldots\ldots \quad (7)$$

Multiply equation (6) by x_i^2

$$x_i^2 \sum y_i = na_0 x_i^2 + a_1 x_i^2 \sum x_i + a_2 x_i^2 \sum x_i^2 + a_3 x_i^2 \sum x_i^3 + \ldots\ldots\ldots + a_n x_i^2 \sum x_i^n \quad .. \quad (8)$$

$$\sum y_i x_i^2 = a_0 \sum x_i^2 + a_1 \sum x_i^3 + a_2 \sum x_i^4 + a_3 \sum x_i^5 + \ldots\ldots\ldots + a_n \sum x_i^{n+2} \qquad \ldots\ldots\ldots \quad (9)$$

Multiply equation (3.85) by x_i^3

$$x_i^3 \sum y_i = na_0 x_i^3 + a_1 x_i^3 \sum x_i + a_2 x_i^3 \sum x_i^2 + a_3 x_i^3 \sum x_i^3 + \ldots\ldots + a_n x_i^3 \sum x_i^n$$

$$\sum y_i x_i^3 = a_0 \sum x_i^3 + a_1 \sum x_i^4 + a_2 \sum x_i^5 + a_3 \sum x_i^6 + \ldots\ldots + a_n \sum x_i^{n+3} \quad \ldots\ldots\ldots \quad (10)$$

Multiply equation (6) by x_i^n

$$x_i^n \sum y_i = a_0 n x_i^n + a_1 x_i^n \sum x_i + a_2 x_i^n \sum x_i^2 + a_3 x_i^n \sum x_i^3 + \ldots\ldots + a_n x_i^n \sum x_i^n$$

$$= a_0 \sum x_i^n + a_1 \sum x_i^{n+1} + a_2 \sum x_i^{n+2} + a_3 \sum x_i^{n+3} + \ldots\ldots + a_n \sum x_i^{n+n} \quad \ldots\ldots\ n$$

Putting equation (6) to n into matrix form

$$\begin{bmatrix} n & \sum x_i & \sum x_i^2 & \sum x_i^3 & \ldots\ldots \sum x_i^n \\ \sum x_i & \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \ldots\ldots \sum x_i^{n+1} \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \ldots\ldots \sum x_i^{n+2} \\ \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \sum x_i^6 & \ldots\ldots \sum x_i^{n+3} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \sum x_i^n & \sum x_i^{n+1} & \sum x_i^{n+2} & \sum x_i^{n+3} & \ldots\ldots \sum x_i^{n+n} \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \\ \ldots\ldots \\ a_n \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum y_i x_i \\ \sum y_i x_i^2 \\ \sum y_i x_i^3 \\ \ldots \\ \sum y_i x_i^n \end{bmatrix}$$

Solving the matrix equation yields values for constants $a_0, a_1, a_2, a_3, \ldots\ldots a_n$ as the case may be depending on the power of the polynomial. From the above matrix; for our particular case; i.e. polynomial of the third order:

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 \quad (11)$$

The equivalent matrix equation will be; (*n = 3*).

$$\begin{bmatrix} n & \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \sum x_i^5 \\ \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \sum x_i^6 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum y_i x_i \\ \sum y_i x_i^2 \\ \sum y_i x_i^3 \end{bmatrix}$$

3. Results and discussion

Bellow are model prediction to monitor the influence of porosity effect on shigella transport to ground water aquifers are presented in tables and figures.

Figure 1 shows that the degree of porosity experienced it optimum degree at 0.2m, and it gradually increase to the level where the lowest degree of porosity where observed, while the experimental values experienced fluctuation between 0.2m and 3.0m and finally observed the lowest degree of porosity in linearly direction at 5.0m. Figure two theoretically values observed vacillation between 0.2m and 0.4 to the point where the optimum value where recorded at 2.5m. fluctuation continue with slight increase at 4.0m and final recorded another lower degree of porosity at 5.m while that of the experiment values maintained fluctuation in the same vein, the optimum value where recorded at 0.4m and it increase in fluctuation with respect to variation in distance to where the lowest rate where recorded at 5.m.

Table 1
Comparison of Theoretical and Experimental values of degree of porosity at various Depths.

Depth mm	Theoretical Values	Experimental Values
200	0.2	0.18
400	0.21	0.24
800	0.23	0.26
1000	0.24	0.21
1200	0.25	0.27
1400	0.28	0.25
1600	0.29	0.27
1800	0.31	0.33
2000	0.33	0.35
2500	0.39	0.41
3000	0.45	0.43
4000	0.59	0.55
5000	0.7	0.67

Table 2
Comparison of Theoretical and Experimental values of degree of porosity at various Depths.

Depth mm	Theoretical Values	Experimental Values
200	0.15	0.14
400	0.14	0.13
800	0.13	0.15
1000	0.13	0.14
1200	0.129	0.125
1400	0.125	0.12
1600	0.122	0.124
1800	0.118	0.116
2000	0.116	0.115
2500	0.11	0.13
3000	0.116	0.117
4000	0.104	0.102
5000	0.11	0.12

Table 3
Comparison of Theoretical and Experimental values of degree of porosity at various Depths.

Depth mm	Theoretical Values	Experimental Values
200	0.2	0.18
400	0.21	0.23
800	0.23	0.25
1000	0.24	0.21
1200	0.25	0.27
1400	0.28	0.26
1600	0.29	0.31
1800	0.31	0.34
2000	0.33	0.36
2500	0.39	0.37
3000	0.45	0.43
4000	0.59	0.56
5000	0.7	0.72

Table 4
Comparison of Theoretical and Experimental values of degree of porosity at various Depths

Depth mm	Theoretical Values	Experimental Values
200	0.27	0.25
400	0.26	0.24
800	0.28	0.31
1000	0.3	0.27
1200	0.32	0.35
1400	0.34	0.31
1600	0.36	0.36
1800	0.39	0.41
2000	0.39	0.36
2500	0.41	0.39
3000	0.57	0.61
4000	0.73	0.75
5000	0.88	0.85

Table 5
Comparison of Theoretical and Experimental values of degree of porosity at various Depths

Depth mm	Theoretical Values	Experimental Values
200	0.19	0.17
400	0.19	0.18
800	0.16	0.16
1000	0.15	0.14
1200	0.14	0.12
1400	0.13	0.16
1600	0.13	0.15
1800	0.12	0.14
2000	0.11	0.13
2500	0.1	0.12
3000	0.09	0.09
4000	0.08	0.08
5000	0.08	0.07

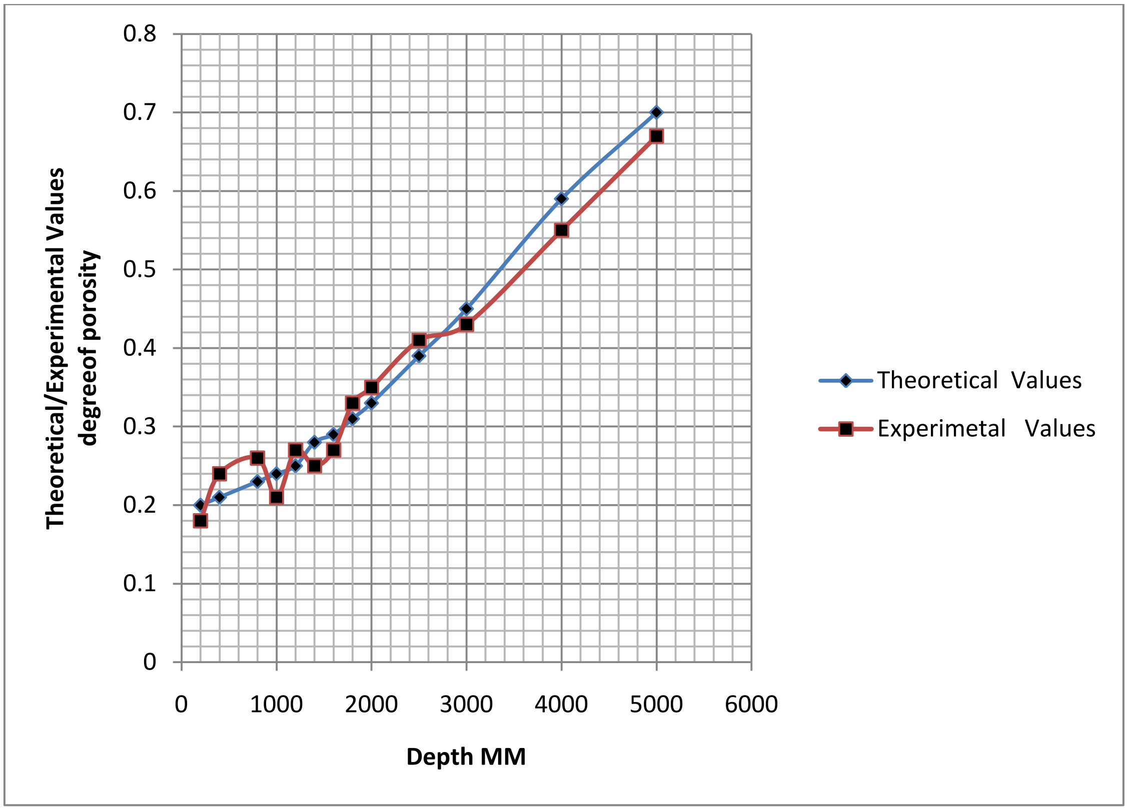


Fig. 1. Comparison of theoretical and experimental values of degree of porosity at various depths.

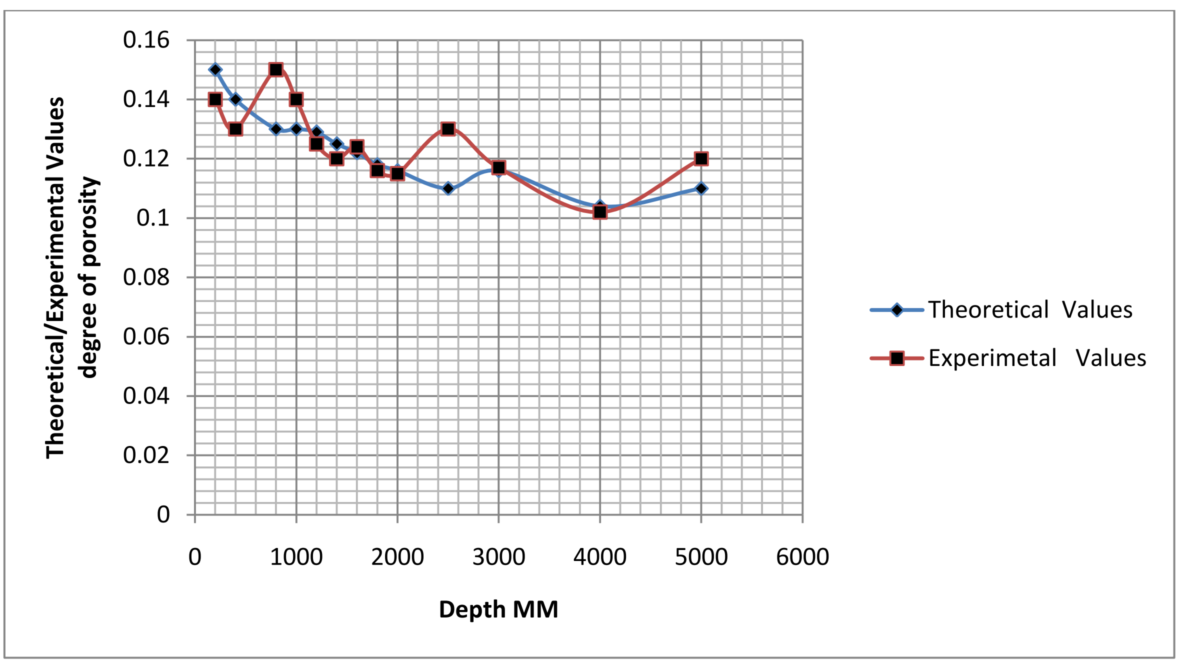


Fig. 2. Comparison of theoretical and experimental values of degree of porosity at various depths.

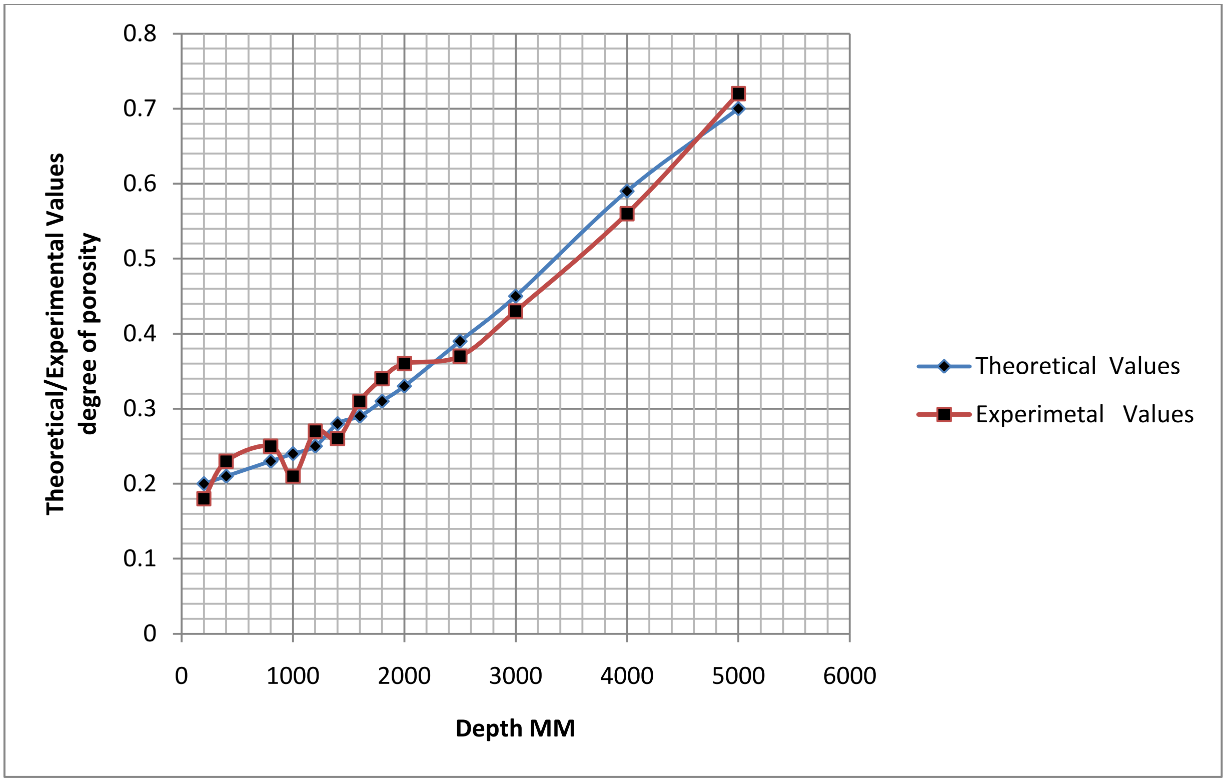


Fig.3. Comparison of theoretical and experimental values of degree of porosity at various depths.

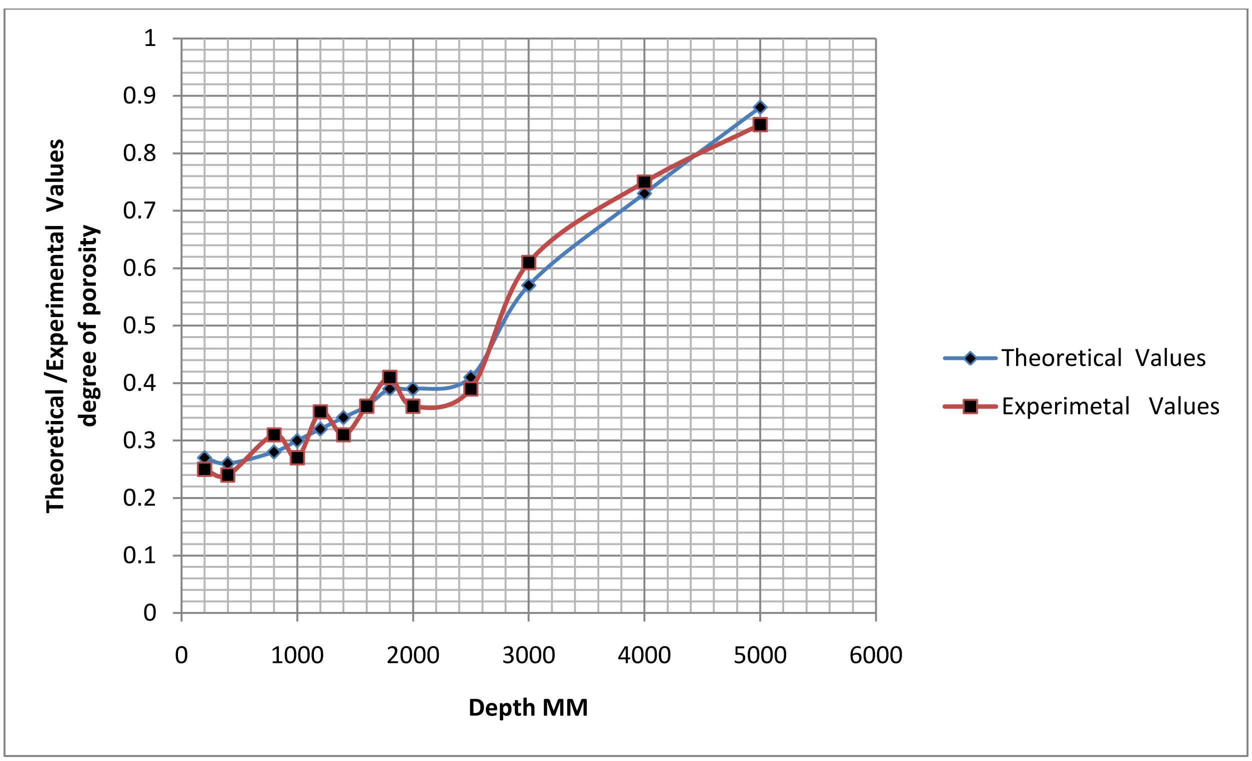


Fig.4. Comparison of theoretical and experimental values of degree of porosity at various depths.

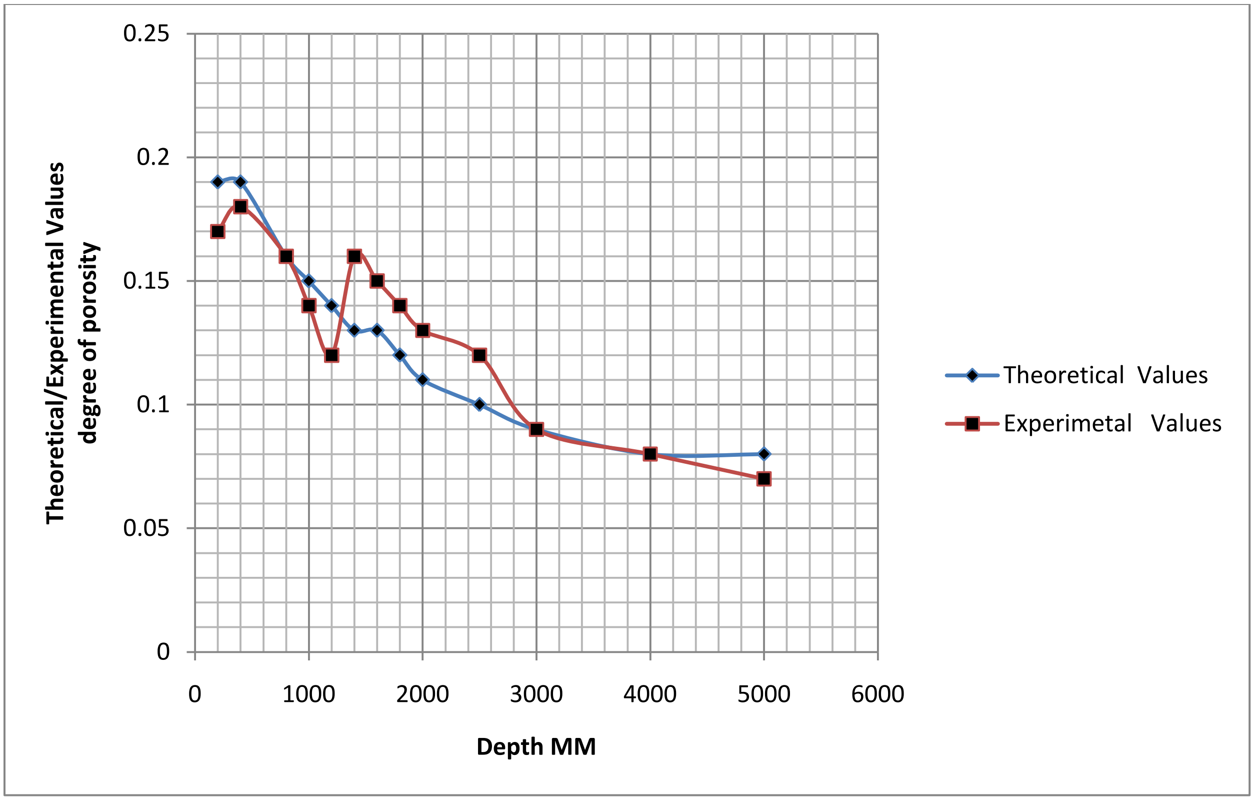


Fig.5. Comparison of theoretical and experimental values of degree of porosity at various depths.

Figure three observed the highest degree between 0.2m to 2.5 meter sudden decrease where observed as the lowest level degree of porosity recorded between 3.m and 5.m, while that of the experimental level observed a fluctuation between 0.2m and 2.5m, low degree of porosity where finally observed in a linear level from 3.m and 5.m. Figure four observed similar condition like figure three, fluctuation where experienced between 0.2 and 2.8m where the highest degree of porosity where observed, sudden decrease of porosity where experienced between 3 to 5m while experimental values maintained similar rate of porosity where the highest degree where recoded between 0.2m and 2m, and the lowest degree where suddenly observed between 3 and 5m. Figure five observed the lowest at 0.2m it gradually experienced increase in degree of porosity to the point where the highest rate where recorded at 5.m while similar condition where also experienced on experimental values, the lowest degree of porosity where observed at 0.2m, fluctuation where recorded between 0.4m and 3m constant increase degree of porosity where experience from 4 to 5m, where the highest where recorded.

The predictive model of porosity are determine through soil stratification, soil structural deposition influence the rate of porosity at different formation, since microbes are deposited solute, the rate of porosity determine there rate of deposition, porosity of soil experience a lots of variation base on several conditions, this influence also affects the transport of shigella in soil and water environment. Shigella behaviors are influenced in several conditions through the variation and deposition of porosity rate at different formation. The effects on shigella transport definitely affect the variation of concentration at different aquifers zone. The study is imperative because the rate of shigella concentration can be monitored through the determination of the porosity degrees at various formations.

4. Conclusion

The influence of porosity on shigella transport to ground water aquifer has been thoroughly evaluated, the degree of porosity at various formation where thoroughly, analyzed fluctuation where experienced at different location as presented in the figures, the study area are predominant with Alluvia deposition. The Alluvia deposited sediment can vary considerably flood plain deposit, it consist of extremely fine silt, whereas coarse gravel or sand may be more typical of Alluvia fine deposit. The deposition of Alluvia deposit a predominant flood plain deposits, that are usually fine grained, well rounded and generally well sorted. Therefore, the porosity in such deposited formation are confirmed to be excellent, but it influence the hydraulic conductivity, depending on the average grain size, more so if gradient of a river steepens or the discharge increase, the sediment will become coarse and thus hydraulic conductivity will be higher, the study location from the geologic history were found to deposit such type of formation and that reflect on the influence of porosity is shigella transport in the study area.

References

Barr, D.W., 2001. Coefficient of permeability determined by measurable parameters. Ground Water, 39, no. 3, 356-361.

Boadu, F.K., 2000. Hydraulic conductivity of soils from grain-size distribution: new models. Journal of Geotechnical and Geoenvironmental Engineering, 126, no. 8, 739-746.

Tina, H., 2006**.** Environmental Isotopic and Hydrochemical Characteristics of Groundwater from the Cretaceous-Eocene Limestone Aquifer in the Keta Basin, Ghana, and the Coastal Sedimentary Basin of Togo Ph.D. Thesis, Geological Institute Faculty of Science, University of Copenhagen

Chapuis, R.P., 2004. Predicting the saturated hydraulic conductivity of sand and gravel using effective diameter and void ratio. Journal of Canadian Geotechnology, 41, 787-795.

Chapuis, R.P., Aubertin, M., 2003. On the use of the Kozeny-Carman equation to predict the hydraulic conductivity of soils. Journal of Canadian Geotechnology, 40, 616-628.

Conrad, C.M., 2006. Air-based measurement of permeability in pebbly sands. Masters Thesis, Department of Geological Sciences, Wright State University, Dayton, OH, 55 p.

Conrad et al. 2007. Air-based measurement of permeability in pebbly sands. (Unpublished).

Costa, A., 2006. Permeability-porosity relationship: A reexamination of the Kozeny- Carman equation based on a fractal pore-space geometry assumption.Geophysical Research Letters, 33, 1-5.

Kamann, P.J., 2004. Porosity and permeability in sediment mixtures. Masters Thesis, Department of Geological Sciences, Wright State University, Dayton, OH, 51 p.

Koltermann, C.E., Gorelick, S.M., 1995. Fractional packing model for hydraulic conductivity derived from sediment mixtures. Water Resources Research, 31, no. 12, 3283-3297.

Revil, A., Cathles, L.M., 1999. Permeability of shaly sands. Water Resources Research, 35, no. 3, 651-662.

Revil, A., Grauls, D., Brévart, O., 2002. Mechanical compaction of sand/clay mixtures. Journal of Geophysical Research, 107, no. B11, 2293.

Peter, M.P., 2005. Porosity and permeability of bimodal sediment mixtures using natural sediment A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science.