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**Research article**

# PREDICTIVE MODELS OF SOIL FORMATION FROM VOID RATIO TO CONFIRM PSEUDOMONAS DEPOSITION IN CAOSTAL AREA OF RIVERS STATE, NIGERIA

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## Abstract

Predictive models of soil formation from void ratio to confirm pseudomonas deposition in coastal area has been assessed, the predictive values were developed from experimental values that produced an equation for ten locations, and the model equations were resolved, it produce theoretical values of void ratio in coastal area of Rivers State. The results produced the model equations from a thorough laboratory analysis for void ratio. These predictive values were compared with other values from other locations. It produced a fitting expression, showing the level of the model validation. The model expression results can be applied to predict the rate of hydraulic conductivity in coastal areas. It can also be applied to monitor the rate of microbial transport with increase in depth between short periods of time in coastal areas of Rivers State. This model is imperative because it will monitor the rate of transport to ground water aquifer, it will also improve the design of quality water in costal area of Rivers State.

**Keywords**: soil, Nigeria, River, modeling fluid flow, phosphorous deposition, organic and lateritic soil

## 1. Introduction

Nigeria has a coastline that is about 1000km long with the Atlantic Ocean, bordering eight states. These are Lagos, Ogun, Ondo, Delta, Bayelsa, Rivers, Akwa Ibom and Cross River States. While the first four states are west of the

River Niger, the last three states are east of the Niger with the last Bayelsa State, straddling the river. Potable water supply to inhabitants in some of the communities in the coastal belt has been a major problem due to salt water intrusion. Communities such as Burutu in Delta State and Aiyetoro in Ondo State have no potable water source as the surface water is salty while all the boreholes drilled so far have yielded saline water. The inhabitants therefore depend on rain harvesting (in the midst of numerous gas flares from oil production platforms) and purchasing water from merchants coming from the hinterland in boats. Since the mid-'80s, many potable water programs have been carried out in Nigeria based on the development of groundwater by the Federal Government and its agencies, States and multi-lateral agencies such as UNICEF and UNDP. Unfortunately many communities in the coastal belt are not benefiting due to perceived difficulties as a result of salt water intrusion. In this paper, a review of the geology of the coastal basins is given followed by a description of the nature of salt water intrusion. Rivers State has a lot of coastal area that has several variations in stratification influences by geologic history of the coastal location. The paper is discuses the application and validation of the predictive model developed for void ratio that is one of the major influences of microbial transport E.coli in the coastal area of Rivers State. Including some constraints in the development and management of potable water in the study location and Nigeria in general. Nigeria is made up of two sedimentary basins: The Benin basin and the Niger Delta basin separated by the Okitipupa ridge (Oteri and Atolagbe, 2003 Oteri 1988, Oteri 1990). The rocks of the Benin basin are mainly sands and shales with some limestone which thicken towards the west and the coast as well as down dips to the coast. Recent sediments are underlain by the Coastal Plains Sands which is then underlain by a thick clay layer - the Ilaro Formation and other older Formations (Jones and Hockey, 1964). The Recent Sediments and Coastal Plains Sands consist of alternation of sands and clays. The Recent Sediments forms a water table aquifer which is exploited by hand-dug wells and shallow boreholes. The Coastal Plains Sands aquifer is a multi-aquifer system consisting of three aquifer horizons separated by silty or clayey layers (Longe et al. 1987). It is the main aquifer in Lagos Metropolis that is exploited through boreholes for domestic and industrial water supply. In the coastal belt of the Benin basin, this aquifer is confined. The Niger Delta is a coastal arcuate delta of the River Niger covering an area of about 75,000km$^2$. The subaerial Niger Delta has an extensive saline/brackish mangrove swamp belt separated from the sea by sand beach ridges for most of the coastline (Oteri and Atolagbe, 2003). Water supply problems relating to salinity are confined to the saline mangrove swamp with associated sandy islands and barrier ridges at the coast. Geologically, rocks of the Niger Delta are Soil surveys furnish basic inputs to soil conservation planning and provide information used in equations for predicting soil loss and water pollution under various management practices on different soils. The quantity and quality of ground water resources of any area are controlled by the climate and geology of the area. The climate through rainfall and surface water resources ensure constant supply or recharge to groundwater resources of an area in a complex hydrological cycle. The geology of the area determines the aquiferous zones where exploitable groundwater may occur and influences the geochemical characteristics of the groundwater, amongst other factors such as human activities (Okereke et al 2011). Nigeria has a long coastline along which many human activities are concentrated. There are two sedimentary basins in Nigeria –the Keta (Dahomey) and the Niger Delta basins. Both the Keta and the Niger Delta basin consist of massive highly porous sands and gravel which form a multi-aquifer system. Saltwater intrusion into unconfined and confined aquifers has occurred in both basins, resulting in borehole abandonment while development of potable water is greatly hampered. In most of the coastal areas, no detailed study to demarcate the interface has been carried out. There is a variable degree of knowledge and management practice, ranging from almost no data and no action to sound conceptual models about aquifer behaviour and comprehensive management actions such as aquifer vulnerability mapping. The variability of hydrogeological settings, the distribution of saline water, and history of groundwater withdrawals and freshwater drainage has resulted in a variety of modes of saltwater intrusion into the coastal aquifer systems. Following the seriousness and rapid degradation of coastal aquifers, there is the need to take actions to manage and prevent saltwater intrusion to ensure a sustainable source of groundwater for the future. There is a strong need for optimal management with options for sustainability in order to simulate and predict the response of the aquifer systems to anticipated increased future levels of groundwater in the area. (Nwankwoala, 2011). Groundwater has been described as the main source of potable water supply for domestic, industrial and agricultural uses in the southern part of Nigeria especially the Niger Delta, due to long retention time and natural filtration capacity of aquifers (Odukoya et al., 2002; Agbalagba et al., 2011; Ehirim and Ofor, 2011). Water that is safe for drinking, pleasant in taste, and suitable for domestic purposes is designated as potable water and must not contain any chemical or biological impurity (Horsfall and Spiff, 1998). Pollution of groundwater has gradually been on the increase especially in our cities with lots of industrial activities, population growth, poor sanitation, land use for commercial agriculture and other factors responsible for environmental degradation (Egila and Terhemen, 2004). The concentration of contaminants in the groundwater also depends on the level and type of elements introduced to it naturally or by human activities and distributed through the geological stratification of the area. It has been reported that petroleum refining contributes solid, liquid, and gaseous wastes in the environment (Ogbuagu, et al., 2011). Some of these wastes could contain toxic components such as the polynuclear aromatic hydrocarbons (PAHs), which have been reported to be the real contaminants of oil and most abundant of the main hydrocarbons found in the crude oil mixture (El-Deeb and Emara, 2005). Once introduced in the environment, PAHs could be stable for as short as 48 hours (e.g. naphthalene) or as long as 400 days (e.g. fluoranthene) in soils (Martens and Frankenberger, 1995). They thus, resist degradation and, remain persistent in sediments and when in organisms, could accumulate in adipose tissues and further transferred up the trophic chain or web (Decker, 1981; Boehm et al., 1981).

## 2 Material and Method

Sample were collect from a bore hole drilling site for ten locations through method of insitu method of sample collection, ten sample were collected in sequence of three metres each, the sample were subjected to standard thorough analysis for void ratio, the experiment performed for the two parameters were determine the rate of influence on this two parameters for microbial transport to ground water aquifers on alluvium deposition. The values

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were plotted and it generates model equations, the equations were resolved and the resolved equation produced theoretical values.

## 3 Results and Discussion

Results and tables on void ratio are presented in tables and figure shown bellow.

**Table: 1 Comparison of Theoretical and measured values of void ratio at Different Depths**

| Depth (m) | Theoretical Values | Measured values |
|---|---|---|
| 3 | 0.24 | 0.25 |
| 6 | 0.21 | 0.23 |
| 9 | 0.19 | 0.19 |
| 12 | 0.16 | 0.18 |
| 15 | 0.13 | 0.14 |
| 18 | 0.11 | 0.12 |
| 21 | 0.008 | 0.009 |
| 24 | 0.005 | 0.007 |
| 27 | 0.003 | 0.004 |
| 30 | 0.003 | 0.002 |

**Table: 2 Comparison of Theoretical and measured values of void ratio at Different Depths**

| Depth (m) | Theoretical Values | Measured values |
|---|---|---|
| 3 | 0.75 | 0.73 |
| 6 | 0.47 | 0.48 |
| 9 | 0.33 | 0.35 |
| 12 | 0.21 | 0.23 |
| 15 | 0.11 | 0.12 |
| 18 | 0.002 | 0.004 |
| 21 | -0.003 | 0.002 |
| 24 | -0.003 | 0.003 |
| 27 | -0.009 | 0.009 |
| 30 | -0.11 | -0.11 |

**Table: 3 Comparison of Theoretical and measured values of void ratio at Different Depths**

| Depth (m) | Theoretical Values | Measured values |
|---|---|---|
| 3 | 0.6 | 0.58 |
| 6 | 0.47 | 0.46 |

| | | |
|---|---|---|
| 9 | 0.36 | 0.38 |
| 12 | 0.27 | 0.25 |
| 15 | 0.2 | 0.22 |
| 18 | 0.14 | 0.16 |
| 21 | 0.1 | 0.1 |
| 24 | 0.08 | 0.09 |
| 27 | 0.07 | 0.06 |
| 30 | 0.09 | 0.07 |

**Table: 4 Comparison of Theoretical and measured values of void ratio at Different Depths**

| Depth (m) | Theoretical Values | Measured values |
|---|---|---|
| 3 | 0.23 | 0.25 |
| 6 | 0.21 | 0.23 |
| 9 | 0.2 | 0.21 |
| 12 | 0.18 | 0.2 |
| 15 | 0.17 | 0.18 |
| 18 | 0.15 | 0.16 |
| 21 | 0.14 | 0.15 |
| 24 | 0.12 | 0.13 |
| 27 | 0.11 | 0.12 |
| 30 | 0.1 | 0.11 |

**Table: 5 Comparison of Theoretical and measured values of void ratio at Different Depths**

| Depth (m) | Theoretical Values | Measured values |
|---|---|---|
| 3 | 0.38 | 0.37 |
| 6 | 0.29 | 0.31 |
| 9 | 0.23 | 0.25 |
| 12 | 0.3 | 0.32 |
| 15 | 0.19 | 0.17 |
| 18 | 0.18 | 0.19 |
| 21 | 0.17 | 0.18 |
| 24 | 0.14 | 0.16 |
| 27 | 0.08 | 0.09 |
| 30 | 0.04 | 0.05 |

**Table: 6 Comparison of Theoretical and measured values of void ratio at Different Depths**

| Depth (m) | Theoretical Values | Measured values |
|---|---|---|
| 3 | 0.47 | 0.49 |
| 6 | 0.64 | 0.66 |
| 9 | 0.73 | 0.71 |
| 12 | 0.86 | 0.84 |
| 15 | 0.15 | 0.17 |
| 18 | 0.17 | 0.19 |
| 21 | 0.22 | 0.22 |
| 24 | 0.3 | 0.31 |
| 27 | 0.42 | 0.44 |
| 30 | 0.57 | 0.58 |

**Table: 7 Comparison of Theoretical and measured values of void ratio at Different Depths**

| Depth (m) | Theoretical Values | Measured values |
|---|---|---|
| 3 | 0.4 | 0.41 |
| 6 | 0.3 | 0.32 |
| 9 | 0.22 | 0.24 |
| 12 | 0.16 | 0.18 |
| 15 | 0.09 | 0.11 |
| 18 | 0.05 | 0.07 |
| 21 | 0.02 | 0.05 |
| 24 | 0.02 | 0.04 |
| 27 | 0.05 | 0.07 |
| 30 | 0.01 | 0.03 |

**Table: 8 Comparison of Theoretical and measured values of void ratio at Different Depths**

| Depth (m) | Theoretical Values | Measured values |
|---|---|---|
| 3 | 0.41 | 0.43 |
| 6 | 0.45 | 0.42 |
| 9 | 0.48 | 0.46 |
| 12 | 0.47 | 0.45 |
| 15 | 0.43 | 0.41 |
| 18 | 0.43 | 0.39 |
| 21 | 0.41 | 0.43 |
| 24 | 0.4 | 0.42 |
| 27 | 0.42 | 0.44 |
| 30 | 0.47 | 0.45 |

**Table: 9 Comparison of Theoretical and measured values of void ratio at Different Depths**

| Depth (m) | Theoretical Values | Measured values |
|---|---|---|
| 3 | 0.32 | 0.34 |
| 6 | 0.37 | 0.34 |
| 9 | 0.38 | 0.4 |
| 12 | 0.36 | 0.35 |
| 15 | 0.32 | 0.34 |
| 18 | 0.27 | 0.25 |
| 21 | 0.04 | 0.06 |
| 24 | 0.06 | 0.08 |
| 27 | 0.18 | 0.18 |
| 30 | 0.27 | 0.25 |

**Table: 10 Comparison of Theoretical and measured values of void ratio at Different Depths**

| Depth (m) | Theoretical Values | Measured values |
|---|---|---|
| 3 | 0.27 | 0.28 |
| 6 | 0.29 | 0.31 |
| 9 | 0.3 | 0.31 |
| 12 | 0.34 | 0.36 |
| 15 | 0.34 | 0.32 |
| 18 | 0.35 | 0.37 |
| 21 | 0.36 | 0.34 |
| 24 | 0.4 | 0.41 |
| 27 | 0.47 | 0.49 |
| 30 | 0.58 | 0.56 |

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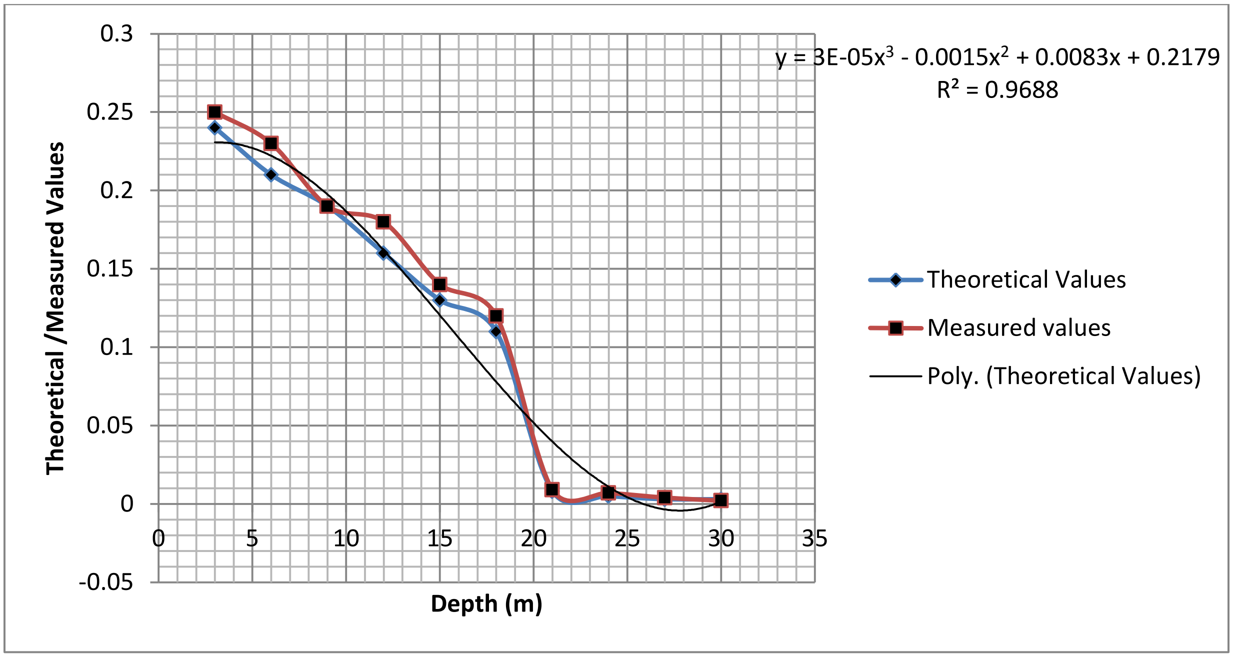


**Figure: 1 Comparison of Theoretical and measured values of void ratio at Different Depths**

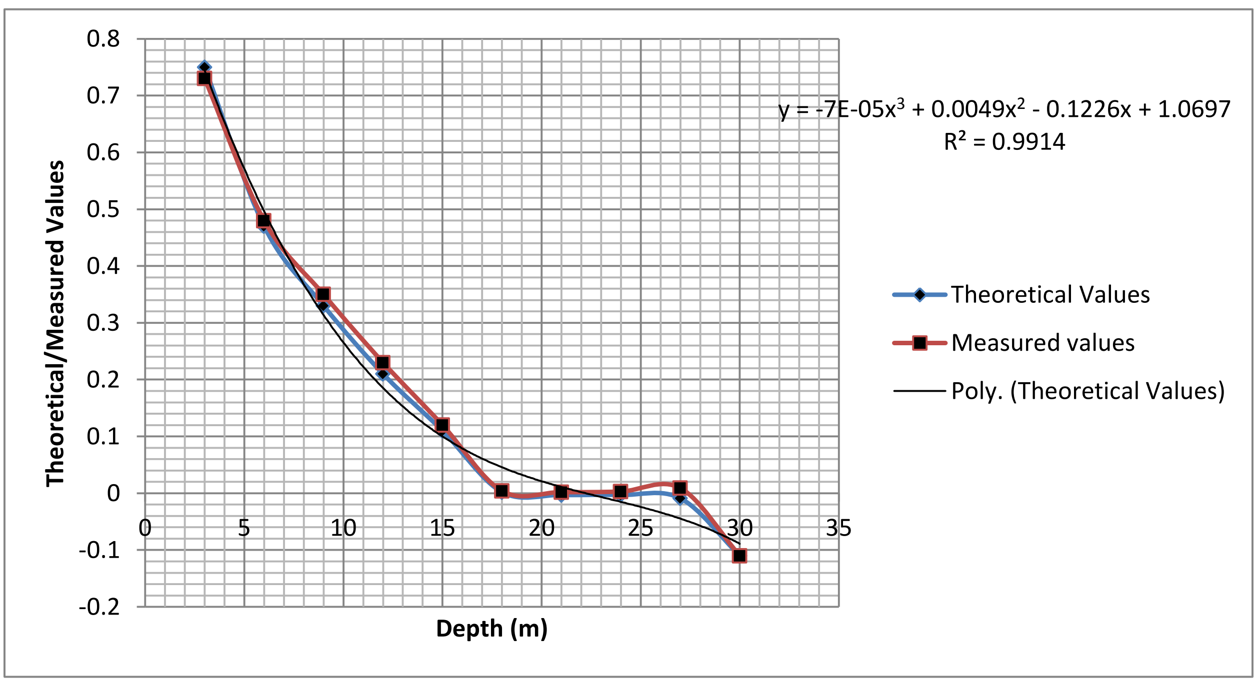


**Figure: 2 Comparison of Theoretical and measured values of void ratio at Different Depths**

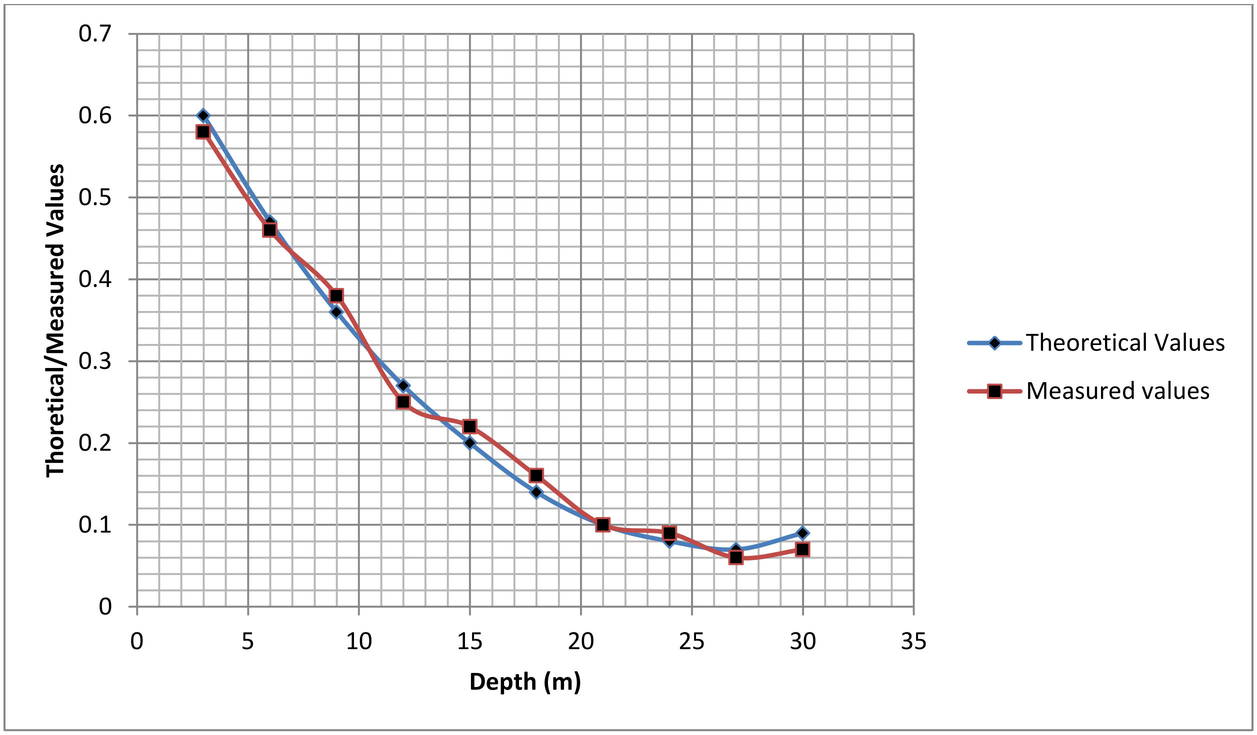


**Figure: 3 Comparison of Theoretical and measured values of void ratio at Different Depths**

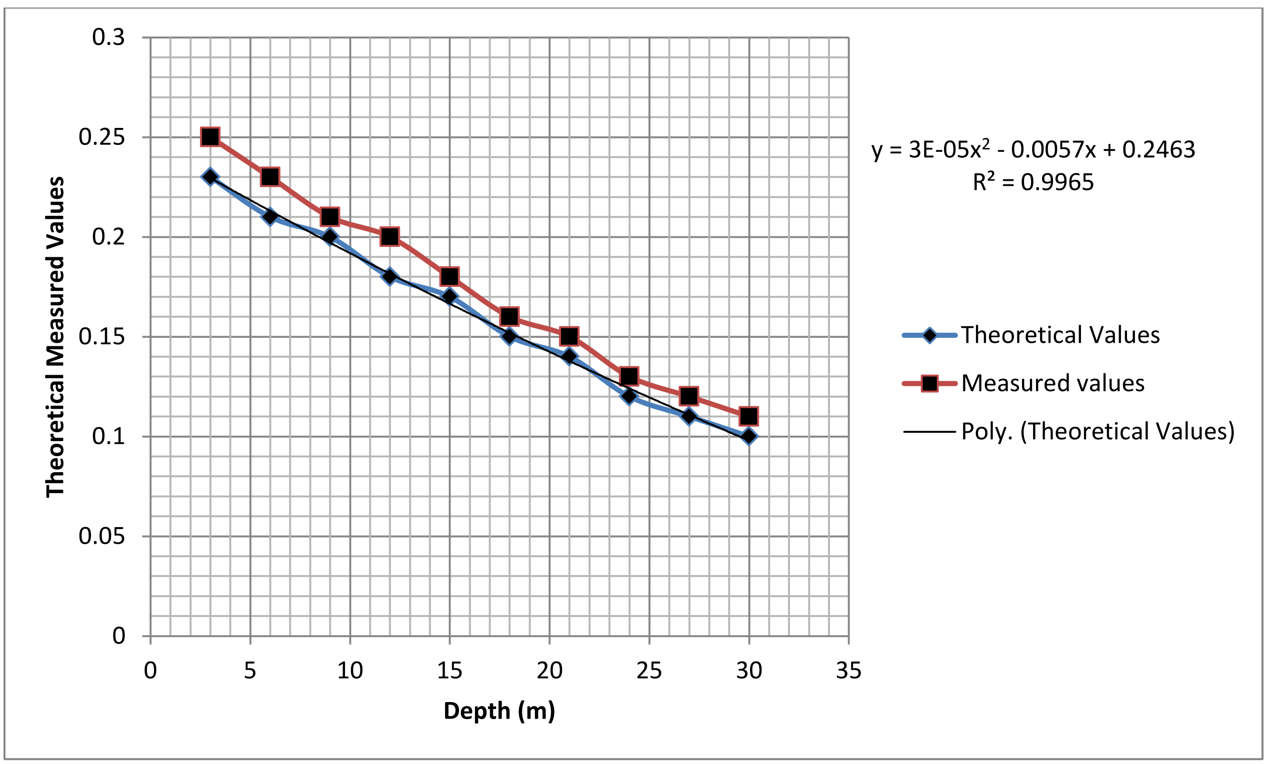


**Figure: 4 Comparison of Theoretical and measured values of void ratio at Different Depths**

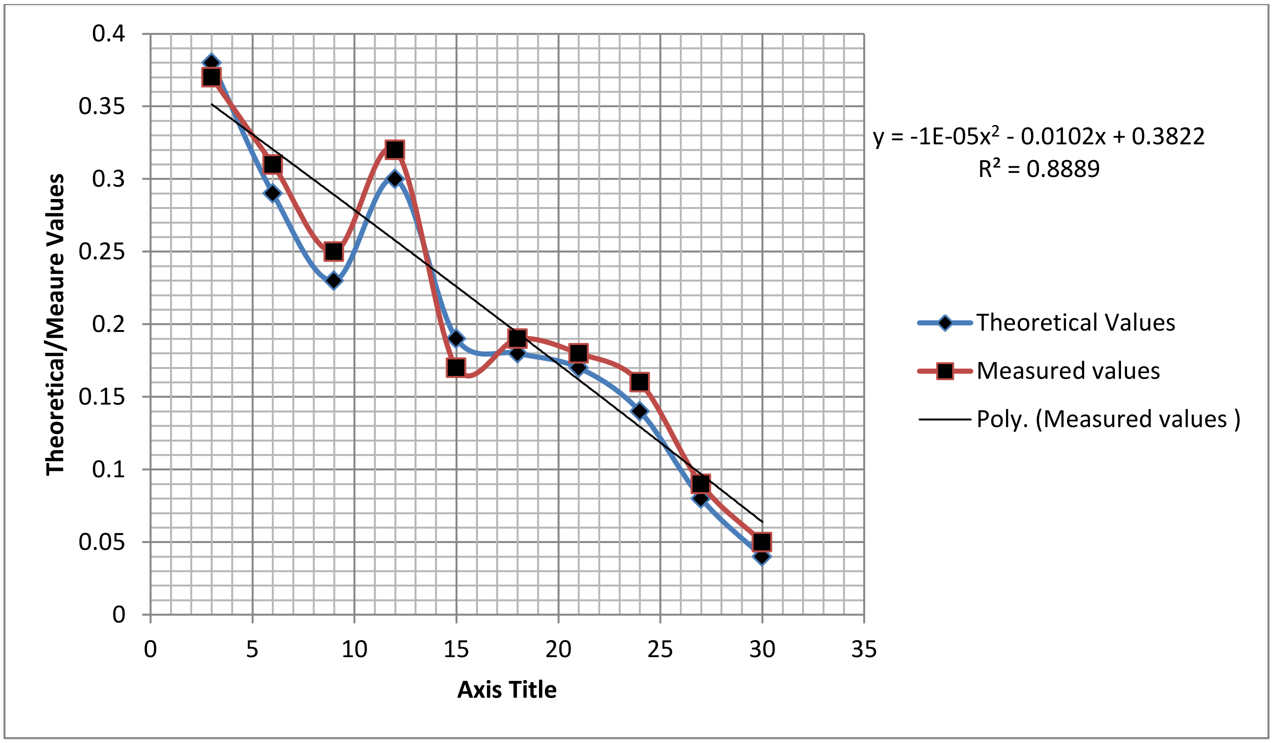


**Figure: 5 Comparison of Theoretical and measured values of void ratio at Different Depths**

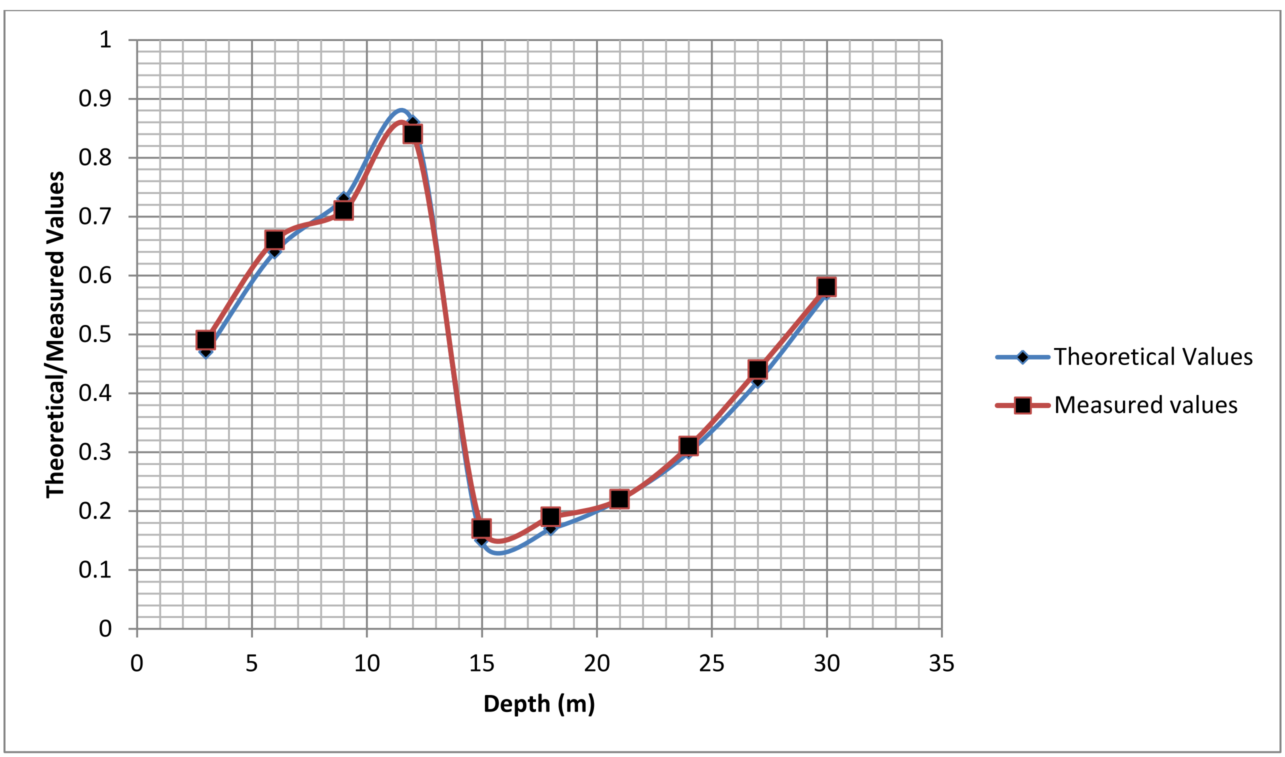


**Figure: 6 Comparison of Theoretical and measured values of void ratio at Different Depths**

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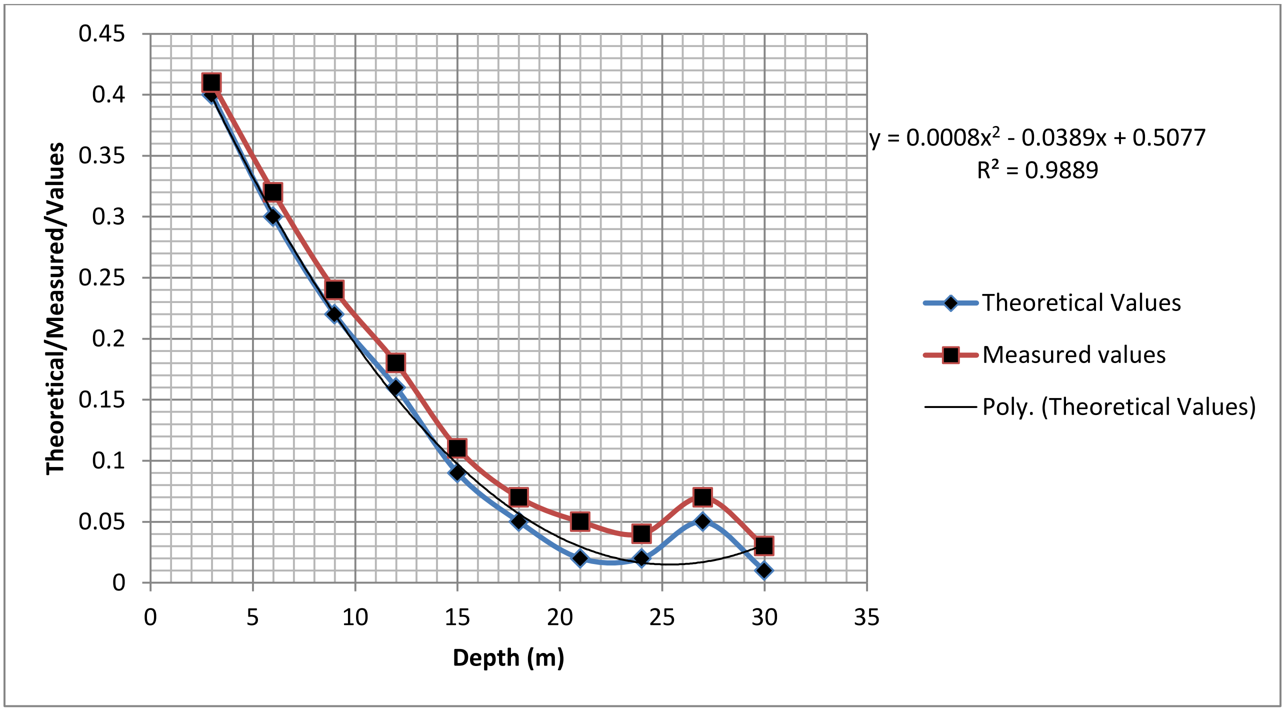


**Figure: 7 Comparison of Theoretical and measured values of void ratio at Different Depths**

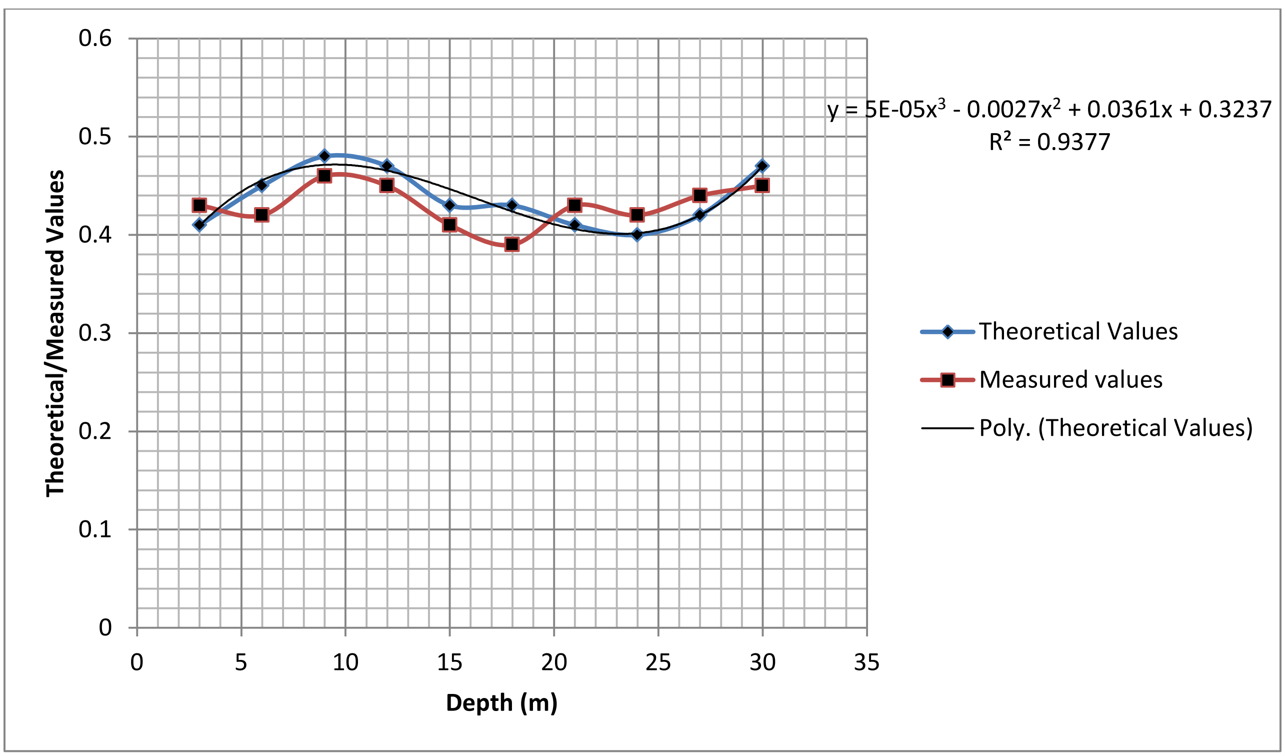


**Figure: 8 Comparison of Theoretical and measured values of void ratio at Different Depths**

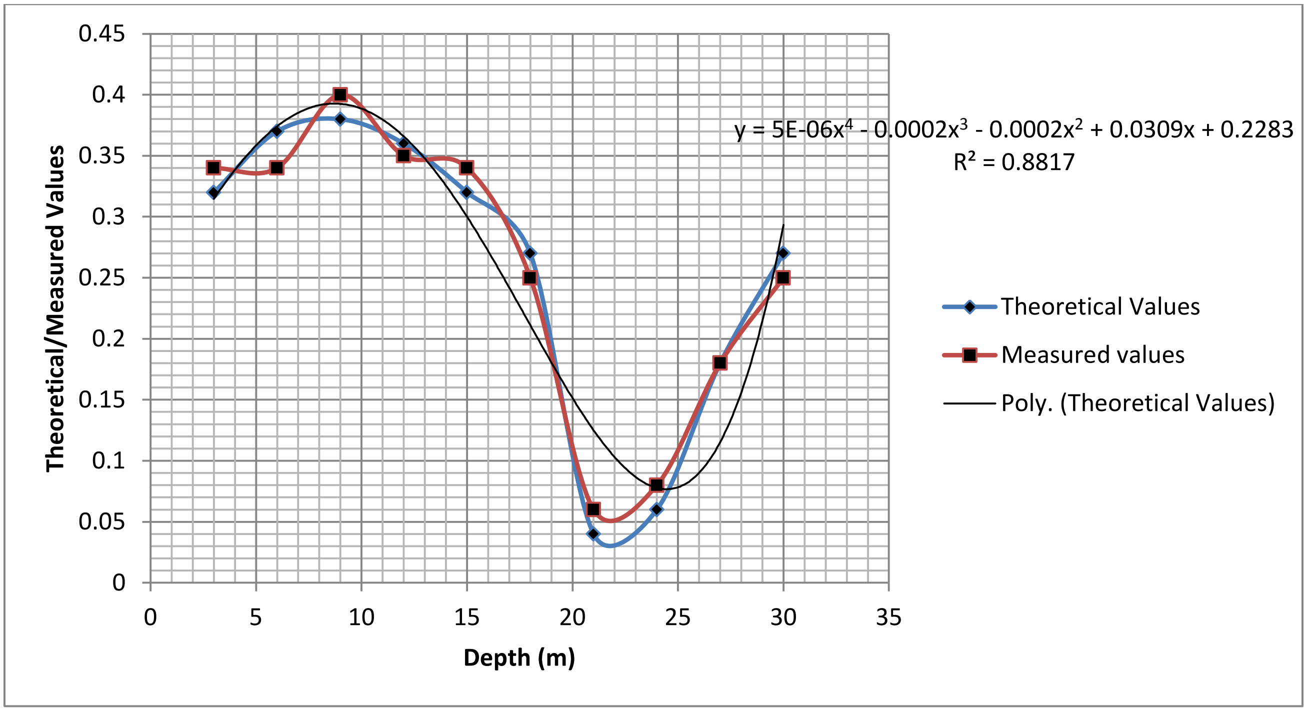


**Figure: 9 Comparison of Theoretical and measured values of void ratio at Different Depths**

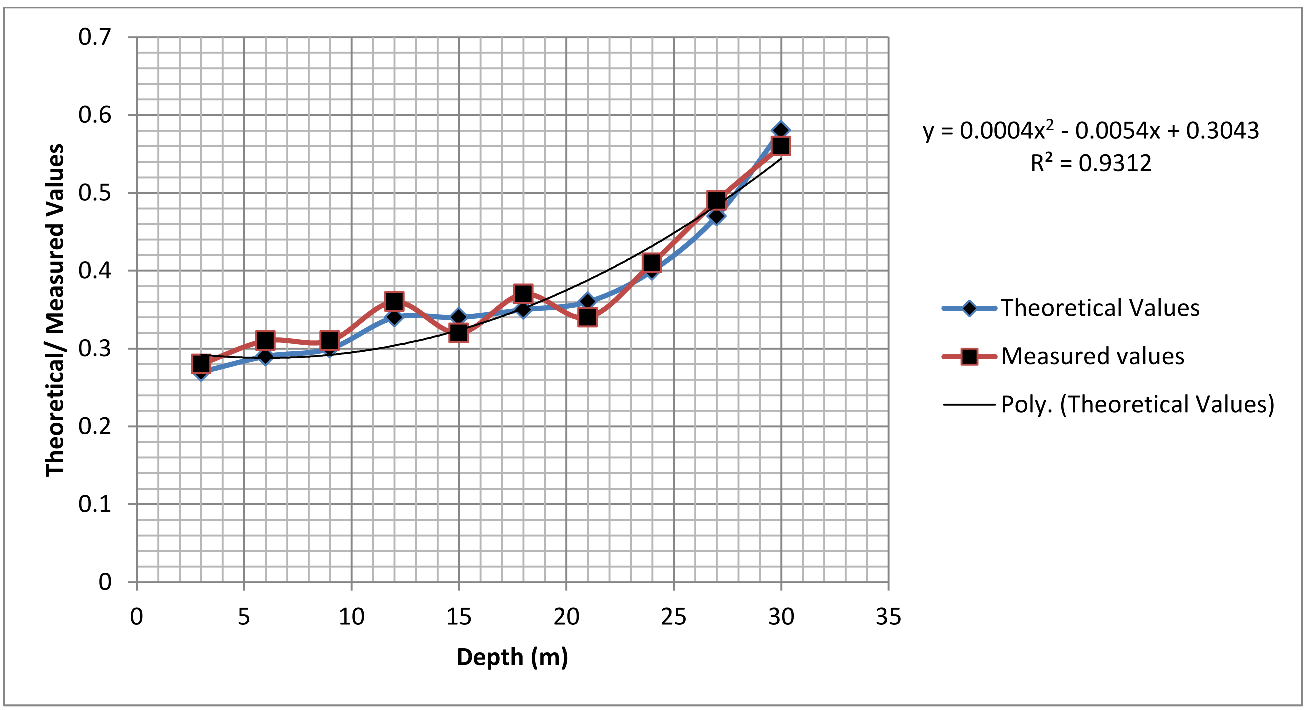


**Figure: 10 Comparison of Theoretical and measured values of void ratio at Different depths**

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Figure 1 shows that the theoretical and measured values increased at three metres, and gradually decrease with increase in depth down to where the lowest degree of void ratio were recorded from twenty one to thirty metres. Similar conditions were observed at figure 2 the highest degree of void ratio for theoretical and measured values deposited at three metres and gradually decrease down to where the lowest degree were recorded at thirty metres. Figure 3 maintained the same condition like figure 2 the highest were recorded at three and gradually decreasing down to the lowest degree of void ratio that deposited at thirty metres. Figure 4 theoretically and measured values linearly decrease with depth from the optimum value at three metres to the lowest degree at thirty metres while in figure 5 both parameters were found to produce an optimum at the same three metres, and suddenly experienced fluctuation from nine metres to thirty metres were the fluctuation were achieved at fifteen metres, finally experienced an increase from eighteen to the lowest thirty metres. Figure 6 maintained similar conditions for both theoretical and measured values but the measured values experienced a slight variation in the optimum values. Figure 7 theoretically and measured value obtained its highest degree of void ratio at three metres and gradually decrease with increase in depth to the point were lowest degree of void ratio were recorded at thirsty metres, while figure 8 theoretical and measured values produced a fluctuation result, generated its optimum values were the highest and lowest degree were found to produce slight difference, both parameters deposited lower degree of void ratio. Figure 9 gradually increased to the point where an optimum value were recorded at nine metres, suddenly decrease were observed to where the lowest degree of void were recorded at twenty one metres and finally it experienced an increase from twenty four to thirty metres. Figure 10 theoretical and measured value developed its highest degree of void ratio at three metres and gradually increases with depth to the optimum were the lowest degrees of void ratio were recorded. All the results of the predictive value were found to compare very well with the measured values, the result of both parameters in six locations producing its highest at three metres and highest degree of void at thirty, it shows that the formation at coastal area has a uniform hydraulic conductivity, deposition in this condition are alluvium deposition, but are found to deposit high rate of hydraulic conductivity, because of the geological formation as foreseen from the soil matrix. The structural depositions of this soil in coastal area explain the shallow aquiferous deposition influence by the geological formation that produced high hydraulic conductivity, base on high degree of void ratio deposited in the soil formation. The shallow aquifer and water table implies that the high degree of void ratio influence more microbial transport as compared to upland area of Rivers State that the degree of void ratio is lower as compared to coastal location.

## 4. Conclusion

The degree of void ratio in coastal area has been thoroughly assessed. The predictive model generated from the experimental result, it has explained the rate of hydraulic conductivity through the figures presented. This value were found to compare favourably well with other values from other locations. The predictive model equations that produced the theoretical value can be applied in the coastal formation, including the rate of hydraulic conductivity in the study area. This condition from the influence of the geologic history is imperative because it can be applied to monitor the rate of microbial transport in coastal area of Rivers State. The results shows how the degree of void ratio influence the rate of hydraulic conductivity and influence the pollution transport from microbes in the coastal area of Rivers State.

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