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Research article

MODELING AND SIMULATION TO MONITOR EXPONENTIAL RATE OF URANIUM IN SILTY FORMATION IN OKWUJAGU OF PORT HARCOURT METROPOLIS, RIVERS STATE OF NIGERIA

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Abstract

Uranium is one of the heavy metals that is poisonous to human health, uranium deposition are found in lateritic and silty formation at a very high percentage,, the rate of regeneration of the substances are depended of the structural setting of the strata, mathematical model were developed to monitor the deposition of the formation in terms of migration at various influenced conditions, the migration process were expressed base on the structural setting of the formation, the developed model considered these established condition in soil structural deposition on the developed governing equations, simulation of the model produced theoretical values, these values were compared with experimental values for model validation, both parameters compared faviourably well, exponential phase was observed in the system expressed from the figures it was few location that experienced fluctuations , the behaviour of uranium deposition was expressed in the figures, the study is imperative because the deposition of uranium in such environment may migrate further if preventive measure are not applied, the developed model if applied will monitor the deposition and migration process of uranium in the study location.

Key words: modeling and simulation. Exponential phase, uranium transport and silty formation.

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1. Introduction

To determine if a given water supply is safe, the source needs to be protected and monitored regularly. There are two broad approaches to water quality monitoring for pathogen detection. The first approach is direct detection of the pathogen itself, for example, the protozoan *Cryptosporidium parvum*. While it will be more accurate and precise if specific disease-causing pathogens are detected directly for the determination of water quality, there are several problems with this approach. First, it would be practically impossible to test for each of the wide variety of pathogens that may be present in polluted water. Second, even though most of these pathogens can now be directly detected, the methods are often difficult, relatively expensive, and time-consuming (WHO, 1996). Instead, water monitoring for microbiological quality is primarily based on a second approach, which is to test for .indicator organisms. For a classification table created by the author of typical indicator organisms). The indicator microorganisms should fulfill the following criteria (Stetler, 1994): The concept which explains the ultimate destination of rainwater is the sea either directly through run off or indirectly be infiltration and subsurface flow. A system of water movement in the atmosphere or rainfall, dews, hailstones or snowfalls over land as run off. Vertical and horizontal movement underground as infiltration or subsurface and continuous movement of all forms of water is the hydrogeology cycle. In the atmosphere, water vapours condense and may give rise to precipitation. However, not all this precipitation will reach the ground surface; some are intercepted by vegetation cover or surface of building and other structures and then evaporate back into the atmosphere. The precipitation that reaches the ground surface may flow in to stream, lake and ocean, where it will either be evaporated or form seepages intruding in to the ground likewise soil moisture and further percolate downward to underline aquifer where it may be held for several years longer. Groundwater in Nigeria is restricted by the fact that more than half of the country is underlain by crystalline basement rock of pre-cambian era. The main rock types in this geological terrain include igneous and metamorphic rock such as migmatites and granite gneisses. Generally in their unaltered form, they are characterized by low porosity and permeability. Porosity in basement rocks is by induction through weathering while secondary permeability induces by tectonic activities which manifest in form of that often act as conduct path facilitating water movement. In other words, aquiferous zones in the basement terrain include fractured/weathered rocks. The yielding capacity of well, drilled within such rock are always very enormous. (Shitta, 2007). Groundwater is the main resource of drinking water in many parts of the world. Contamination resulting from industry, urbanization and agriculture poses a threat to the groundwater quality (Amadi, 2009). The task of balancing groundwater protection and economic activities is challenging. Therefore, understanding the effects of different water management strategies and the role of climate change is essential for the sustainable use of coastal groundwater resources (Prasad and Narayana, 2004). According to Olobaniyi and Owoyemi (2006), the coastal regions of the world are the most densely populated areas in the world. More than one third of the world’s populations are living within 100 km of the coastline (Hughes, et al., 1998). At the same time, the coastal regions provide about one third of the world’s ecosystem services and natural capital (Aris, et al., 2007). Such growth is accompanied by increasing demand for water supply leading to the over-exploitation of the aquifer system and excessive drainage for land reclamation purposes. Contamination of the groundwater by natural means (seawater intrusion) and through anthropogenic means (human activities) cannot be ruled out in the area. The study is aimed at evaluating the quality of groundwater from the coastal plain-sand aquifer Port-Harcourt area with the view of determining its suitability for domestic, irrigational and industrial purposes. The heavy industrial and human activities in the area lead to the present study. The aquifer system in the area is largely unconfined, highly porous and permeable and the possibility of anthropogenic interference cannot be completely ignored, hence the need for this study. Port-Harcourt, the 'garden-city and treasure base of the nation' is situated about 60 km from the open sea lies between longitude 6o55'E to 7o10'E of the Greenwich meridian and latitude 4o38'N to 4o54'N (Fig. 1) of the Equator, covering a total distance of about 804 km2 (Akpokodje 2001). In terms of drainage, the area is situated on the top of Bonny River and is entirely lowland with an average elevation of about 15 m above sea level (Nwankwoala, 2005). The topography is under the influence of tides which results in flooding especially during rainy season (Nwankwoala and Mmom, 2007 Nwankwoala, 2005). Climatically, the city is situated within the sub-equatorial region with the tropical monsoon climate characterized by high temperatures, low pressure and high relative humidity all the year round. The mean annual temperature, rainfall and relative humidity are 30oC, 2,300 mm and 90% respectively (Ashton-Jones, 1998). The soil in the area is mainly silty-clay with interaction of sand and gravel while the vegetation is a combination of mangrove swamp forest and rainforest (Teme, 2002). Port-Harcourt falls within the Niger Delta Basin of Southern Nigeria which is defined geologically by three sub-surface sedimentary facies: Akata, Agbada and Benin formations (Whiteman, 1982). The Benin Formation (Oligocene to Recent) is the aquiferous formation in the study area with an average thickness of about 2100 m at the centre of the basin and consists of coarse to medium grained sandstone, gravels and clay with an average thickness of about 2100 m at the centre of the basin and consists of coarse to medium grained sandstone, gravels and clay (Etu-Efeotor and Akpokodje, 1990). The Agbada Formation consists of alternating deltaic (fluvial, coastal, fluviomarine) and shale, while Akata Formation is the basal sedimentary unit of the entire Niger Delta, consisting of low density, high pressure shallow marine to deep water shale (Schield, 1978).

2. Materials and method

Soil samples from several different boring locations, were collected at intervals of one metre each (30cm). Soil sample were collected in five different location, applying insitu method of sample collection, the soil sample were collect for analysis, standard laboratory analysis were collected to determine the uranium concentration through column experiment, the result were analysed to determine the influence on uranium transport between lateritic and silty soil formation in the study area.

Nomenclature

ϕ = Permeability [LT^{-1}]

C = Concentration of Uranium [MTL^{-3}]

T = Time [T]

y = Distance [L]

$$\theta \frac{\partial c}{\partial t} = D \frac{\partial^2 c}{\partial y^2} \quad \ldots\ldots\ldots\ldots \quad (1)$$

Let $C = T^1 Y$

$$\frac{\partial c}{\partial t} = T^1 Y \qquad \text{………………………….. (2)}$$

$$\frac{\partial^2 c}{\partial y^2} = TY^{11} \qquad \text{………………………….. (3)}$$

$$\theta T^1 Y = DTY^{11} = \gamma^2 \qquad \text{………………………….. (4)}$$

Let $\theta \frac{T^1}{T} = D\frac{Y^{11}}{Y} = -\gamma^2$ ………………………….. (5)

$$\int \frac{dT}{T} = \int \frac{-\lambda^2}{\theta} dt \qquad \text{………………………….. (6)}$$

$$LnT = \frac{-\gamma^2}{\theta} t + a_3 \qquad \text{………………………….. (7)}$$

$$T = \ell^{\frac{-\gamma^2}{\theta} t + a_3} \qquad \text{………………………….. (8)}$$

$$T = C_3 \, \ell^{\frac{-\gamma^2}{\theta} t} \qquad \text{………………………….. (9)}$$

$$D\frac{Y^{11}}{Y} = -\gamma^2 \qquad \text{………………………….. (10)}$$

$$\frac{\partial^2 y}{\partial y^2} + \frac{\gamma^2}{D} y = 0 \qquad \text{………………………….. (11)}$$

Auxiliary equation

$$M^2 + \frac{\gamma^2}{D} = 0 \qquad \text{………………………….. (12)}$$

$$M = \pm i \frac{\gamma}{\sqrt{D}} \qquad \text{………………………….. (13)}$$

$$\therefore\ Y = ACos\frac{\gamma}{\sqrt{D}} y + B\,Sin\frac{\gamma}{\sqrt{D}} y \qquad \text{…………………… (14)}$$

Combine (29) and (34), we have

$$C_2 = TY$$

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$$C_2 = C_3 \ell^{\frac{-\gamma^2}{\theta}t} \; ACos\frac{\gamma}{\sqrt{D}}y + ASin\frac{\gamma}{\sqrt{D}}y \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

4. Results and Discussion

Results and discussion from the expressed figures through the theoretical generated values are presented in tables and figures, the expression explain the rate of concentration through graphical representation for every condition assessed in the developed model equations

Table1: Concentration of Uranium at Different Depths

Depths [m]	Concentration Mg/L
3	1.2
6	4.76
9	10.62
12	18.84
15	29.36
18	42.24
21	57.44
24	74.98
27	94.48
30	117

Table2: Concentration of Uranium at Different Time

Time	Concentration Mg/L
10	1.2
20	4.76
30	10.62
40	18.84
50	29.36
60	42.24
70	57.44
80	74.98
90	94.48
100	117

Table: 3 Comparison of Theoretical and Experimental Values Uranium at Different Depths

Depths [m]	Theoretical Values Mg/L	Experimental Values
3	1.2	1.23

6	4.76	4.33
9	10.62	11.3
12	18.84	18.55
15	29.36	30.1
18	42.24	43.03
21	57.44	56.98
24	74.98	75.44
27	94.48	94.67
30	117	118

Table: 4 Comparison of Theoretical and Experimental Values Uranium at Different Depths

Time	Theoretical Values Mg/L	Experimental Values
10	1.2	1.23
20	4.76	4.33
30	10.62	11.3
40	18.84	18.55
50	29.36	30.1
60	42.24	43.03
70	57.44	56.98
80	74.98	75.44
90	94.48	94.67
100	117	118

Table5: Concentration of Uranium at Different Time

Depths [m]	Concentration Mg/L
3	0.1
6	0.3
9	0.81
12	17.98
15	30.08
18	44.34
21	65.16
24	85.06
27	117.07
30	144.49

Table 6: Concentration of Uranium at Different Time

Time	Concentration Mg/L

10	**0.1**
20	**0.3**
30	**0.81**
40	**17.98**
50	**30.08**
60	**44.34**
70	**65.16**
80	**85.06**
90	**117.07**
100	**144.49**

Table: 7 Comparison of Theoretical and Experimental Values Uranium at Different Depths

Depths [m]	Theoretical Values Variation [K] Values Mg/L	Experimental Values
3	**0.1**	**0.11**
6	**0.3**	**0.32**
9	**0.81**	**0.84**
12	**17.98**	**18.22**
15	**30.08**	**29.88**
18	**44.34**	**44.78**
21	**65.16**	**66.11**
24	**85.06**	**84.99**
27	**117.07**	**118.2**
30	**144.49**	**145.1**

Table: 8 Comparison of Theoretical and Experimental Values Uranium at Different Time

Time	Theoretical Values Variation [K] Values Mg/L	Experimental Values
10	**0.1**	**0.11**
20	**0.3**	**0.32**
30	**0.81**	**0.84**
40	**17.98**	**18.22**
50	**30.08**	**29.88**
60	**44.34**	**44.78**
70	**65.16**	**66.11**
80	**85.06**	**84.99**
90	**117.07**	**118.2**
100	**144.49**	**145.1**

Table9: Concentration of Uranium at Different Depths

Depths [m]	Different Concentration Mg/L

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3	1.2
6	0.26
9	5.28
12	4.83
15	9.7
18	6.55
21	6.01
24	4.08
27	2.74
30	1.89

Table10: Concentration of Uranium at Different Time

Time	Different Concentration Mg/L
10	1.2
20	0.26
30	5.28
40	4.83
50	9.7
60	6.55
70	6.01
80	4.08
90	2.74
100	1.89

Table: 11 Comparison of Theoretical and Experimental Values Uranium at Different Time

Depths [m]	Theoretical Values Variation [K] Values Mg/L	Experimental Values
3	1.2	1.25
6	0.26	0.29
9	5.28	5.67
12	4.83	5.01
15	9.7	8.9
18	6.55	6.45
21	6.01	5.89
24	4.08	4.1
27	2.74	2.65
30	1.89	1.98

Table: 12 Comparison of Theoretical and Experimental Values Uranium at Different Time

Time	Theoretical Values Variation [K] Values Mg/L	Experimental Values
10	1.2	1.25
20	0.26	0.29
30	5.28	5.67
40	4.83	5.01
50	9.7	8.9
60	6.55	6.45
70	6.01	5.89
80	4.08	4.1
90	2.74	2.65
100	1.89	1.98

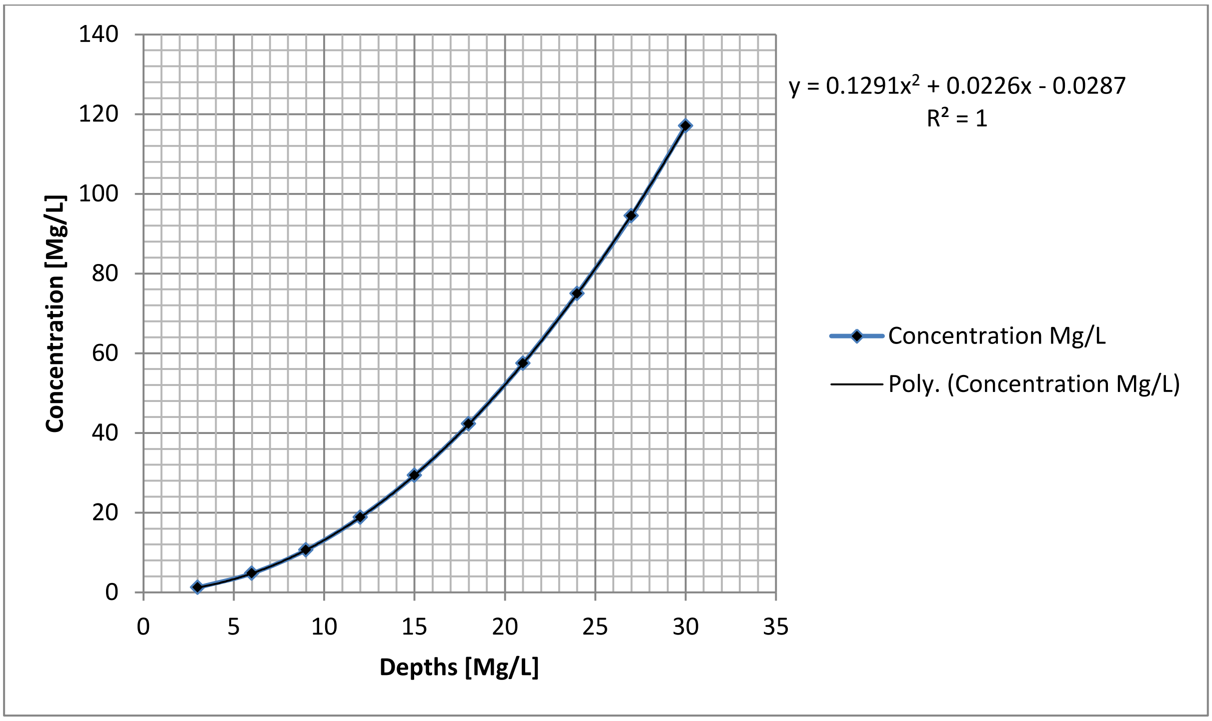

Figure 1: Concentration of Uranium at Different Depths

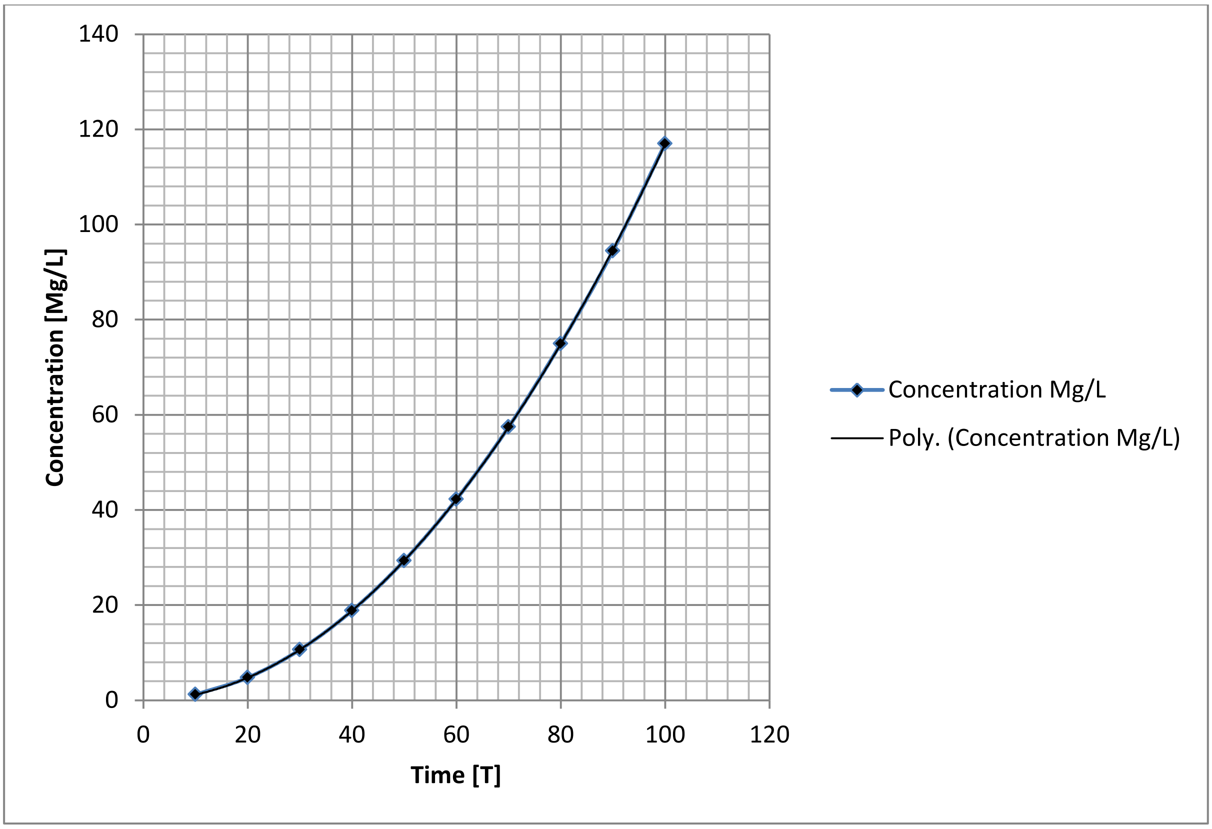

Figure 2: Concentration of Uranium at Different Time

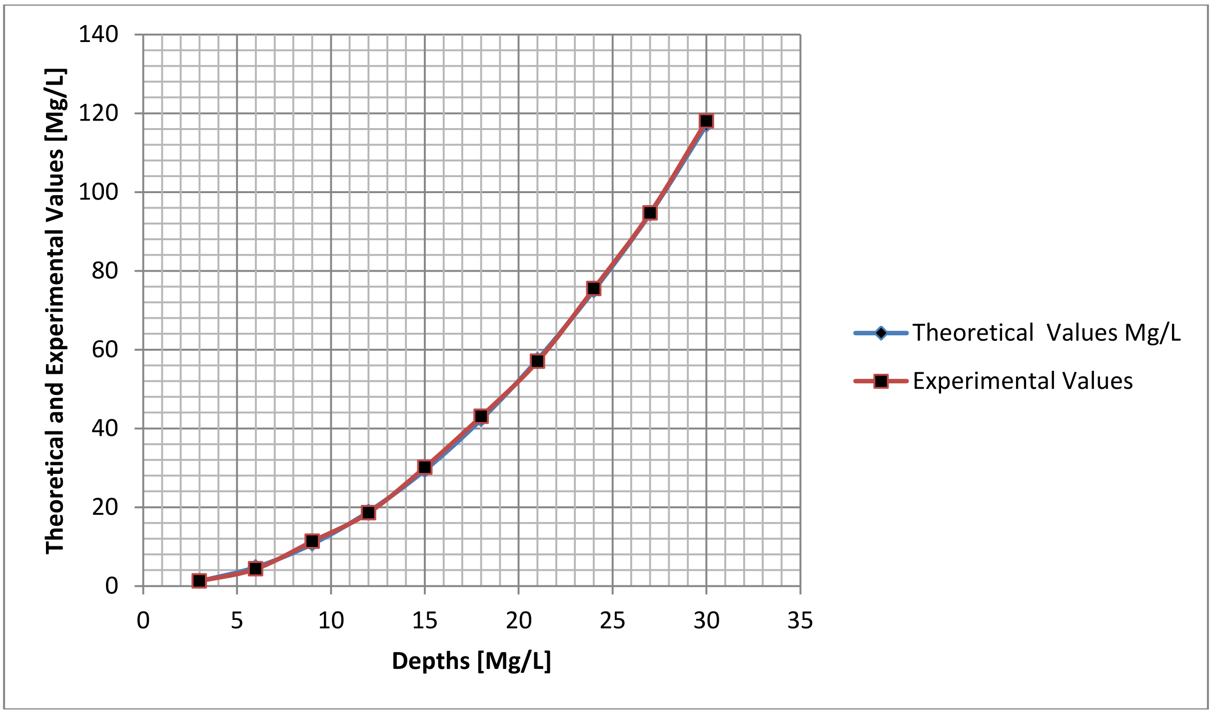

Figure 3: Comparison of Theoretical and Experimental Values Uranium at Different Depths

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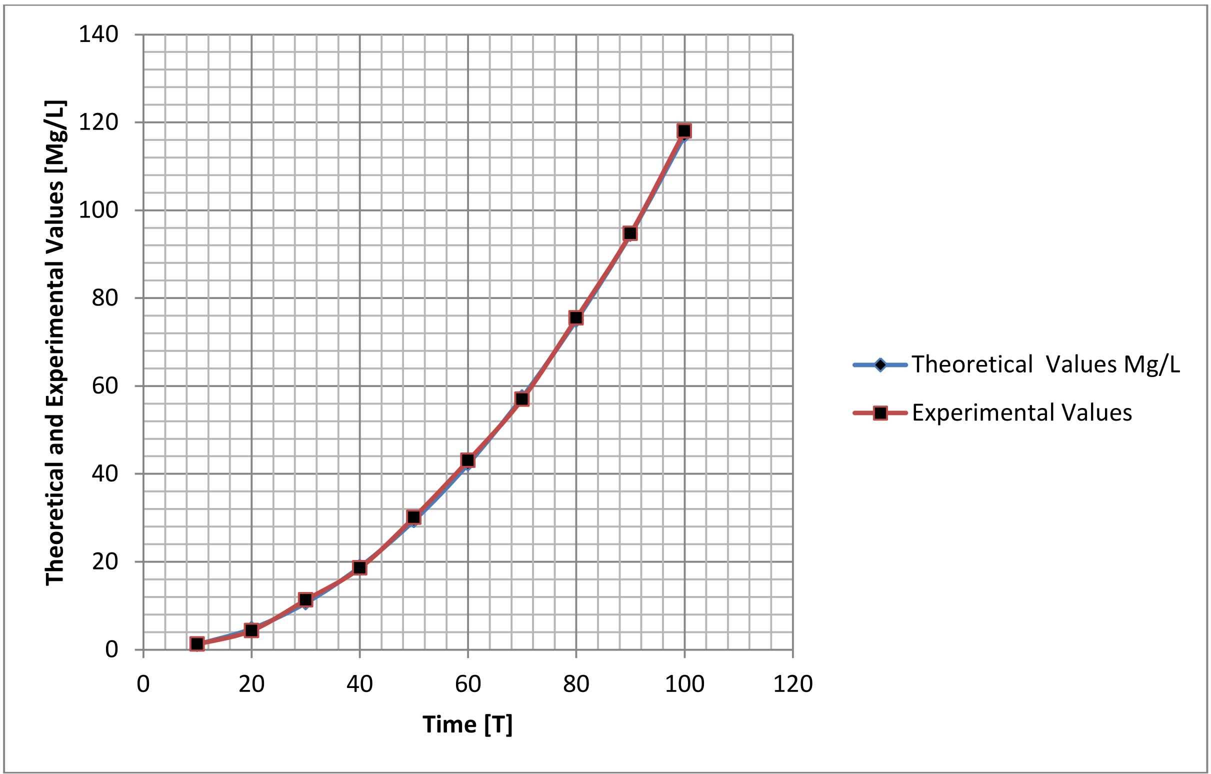

Figure 4: Comparison of Theoretical and Experimental Values Uranium at Different Time

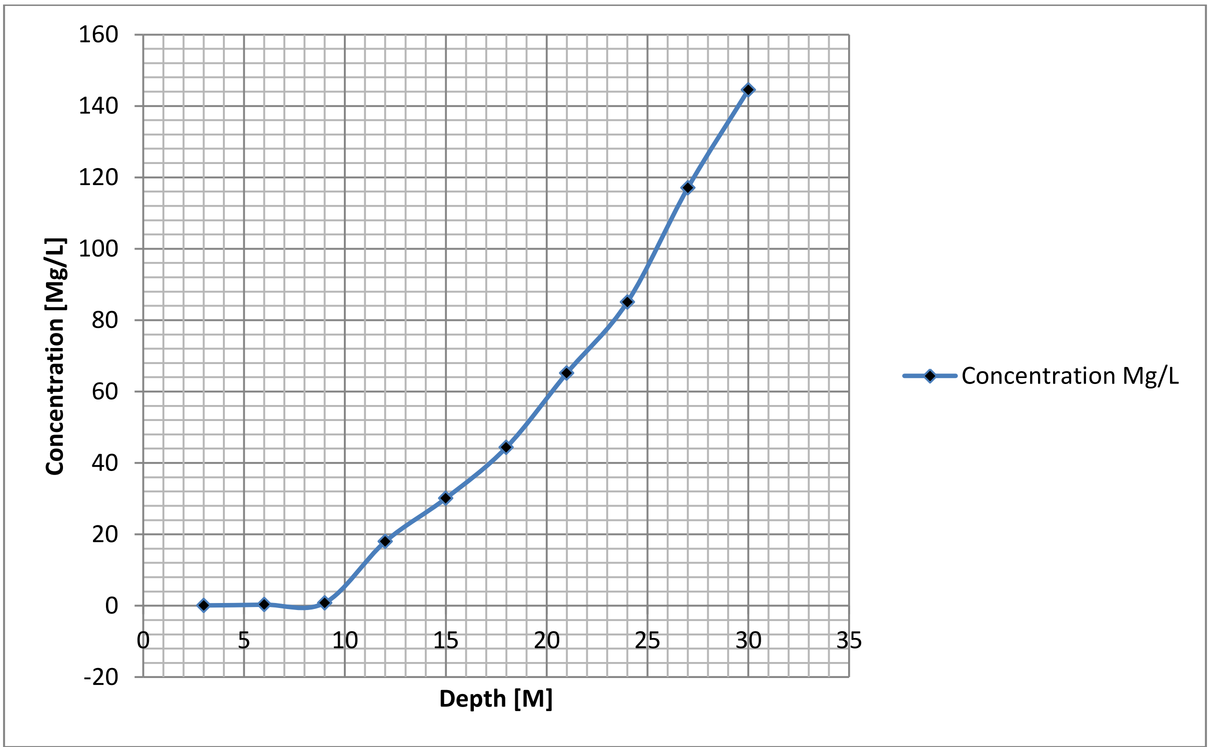

Figure 5: Concentration of Uranium at Different Time

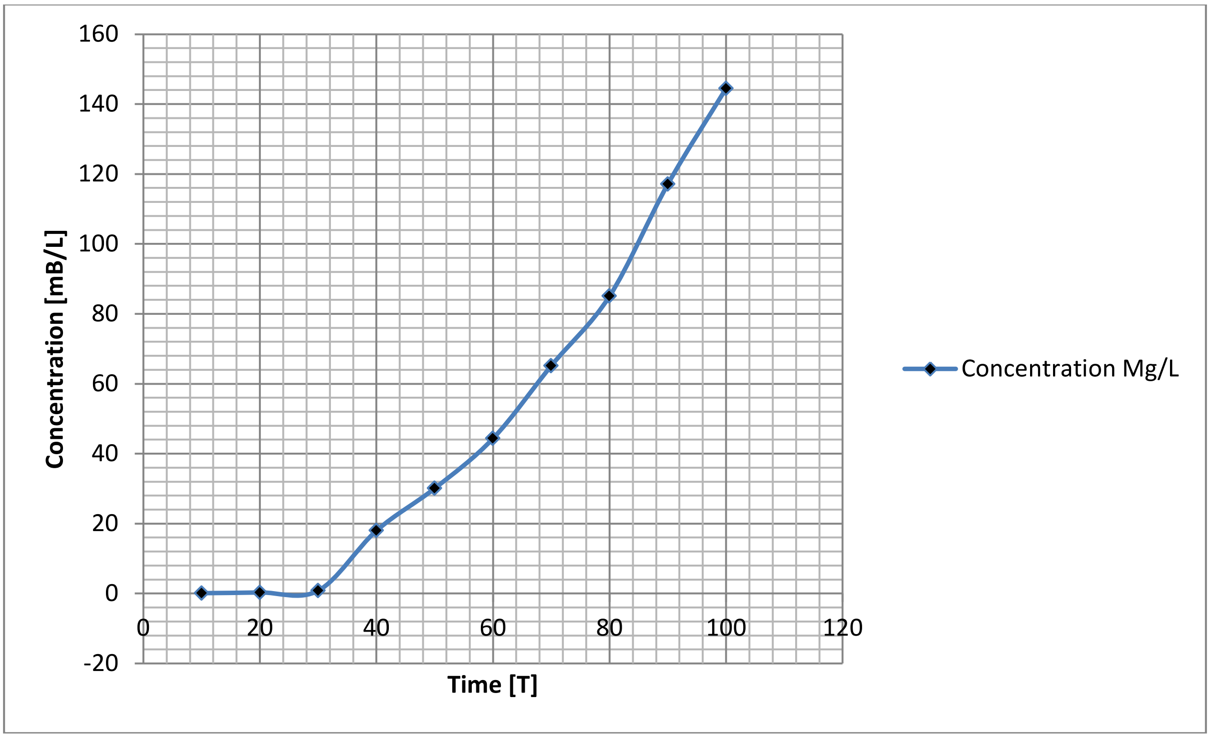

Figure 6: Concentration of Uranium at Different Time

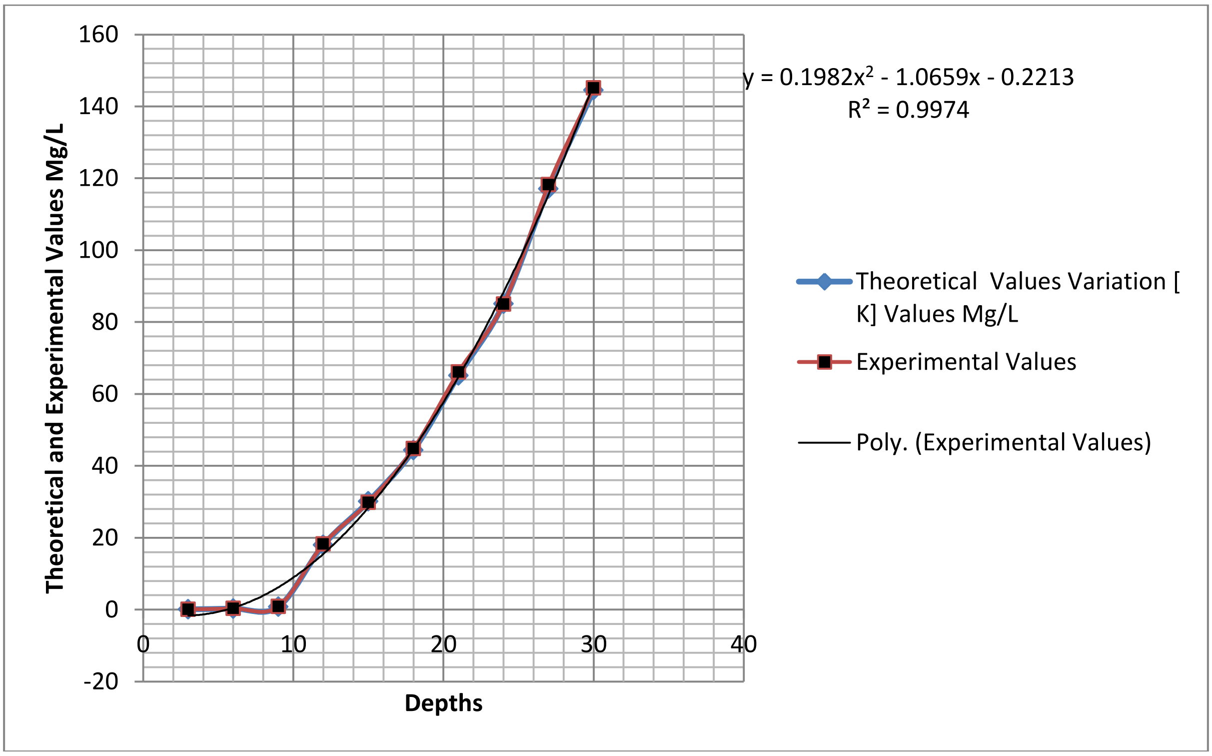

Figure 7: Comparison of Theoretical and Experimental Values Uranium at Different Depths

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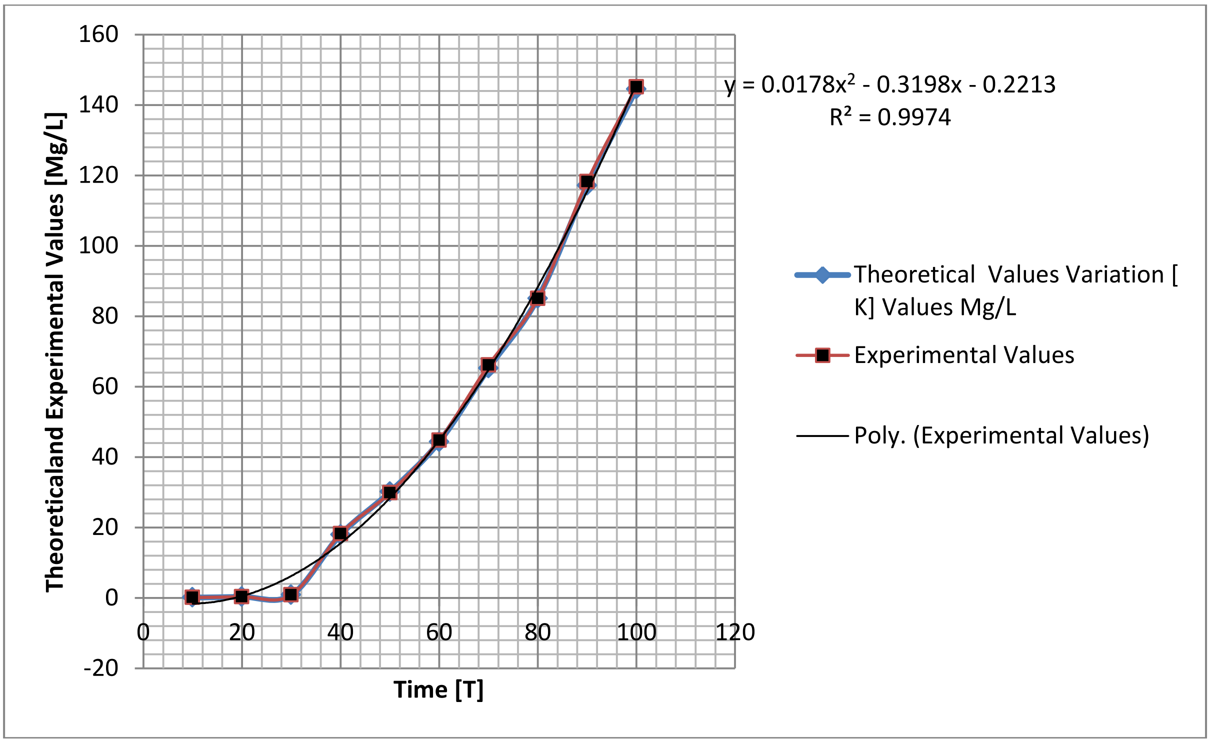

Figure 8: Comparison of Theoretical and Experimental Values Uranium at Different Time

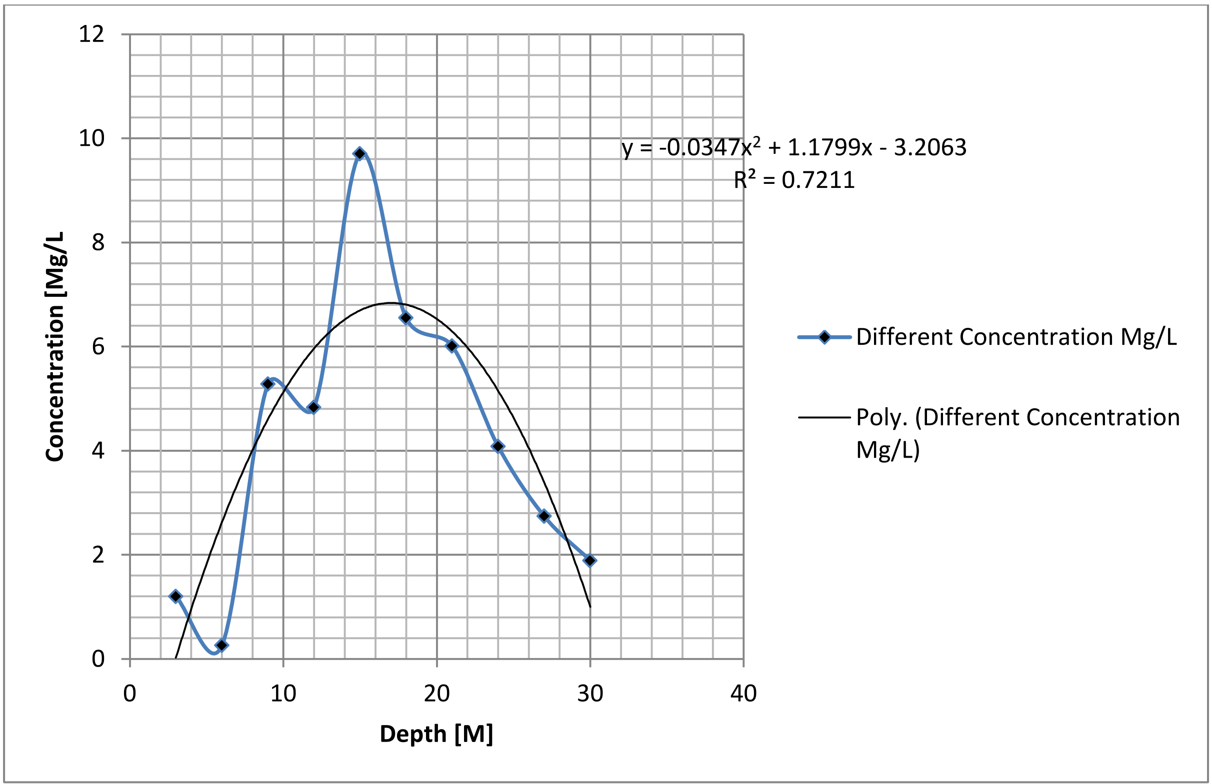

Figure 9: Concentration of Uranium at Different Depths

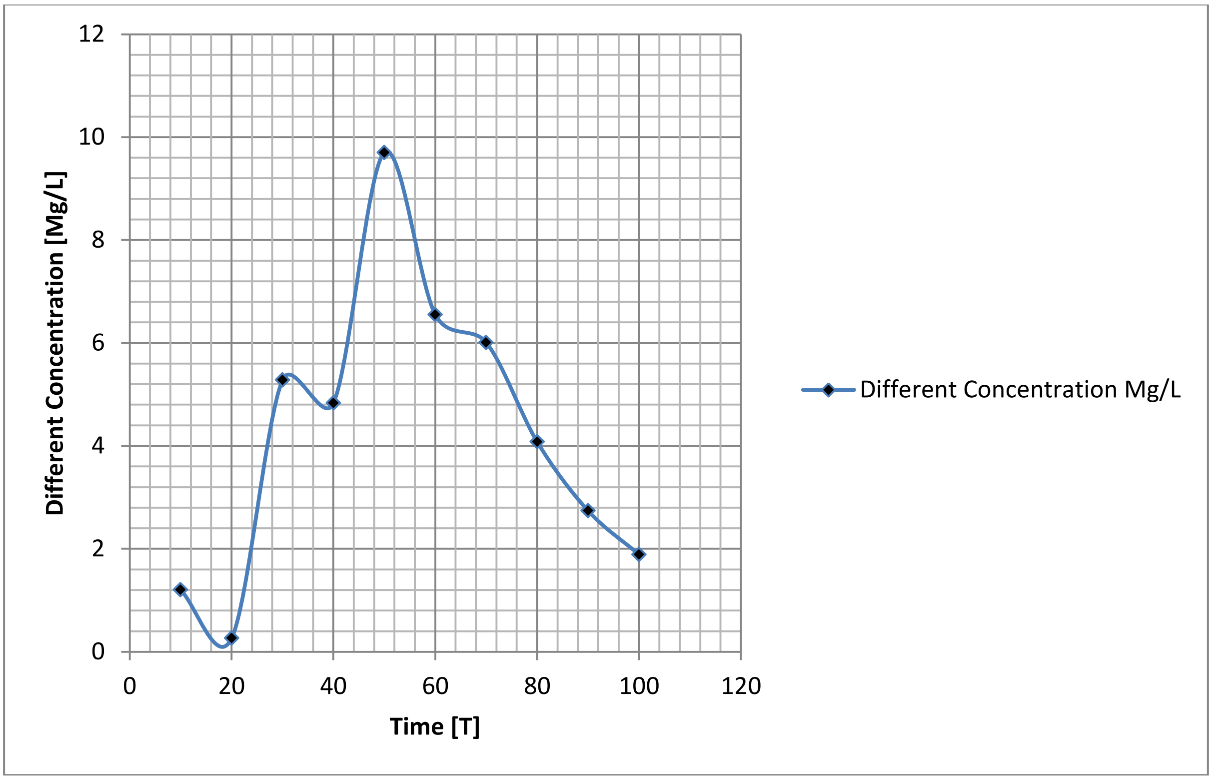

Figure 10: Figure 9: Concentration of Uranium at Different Time

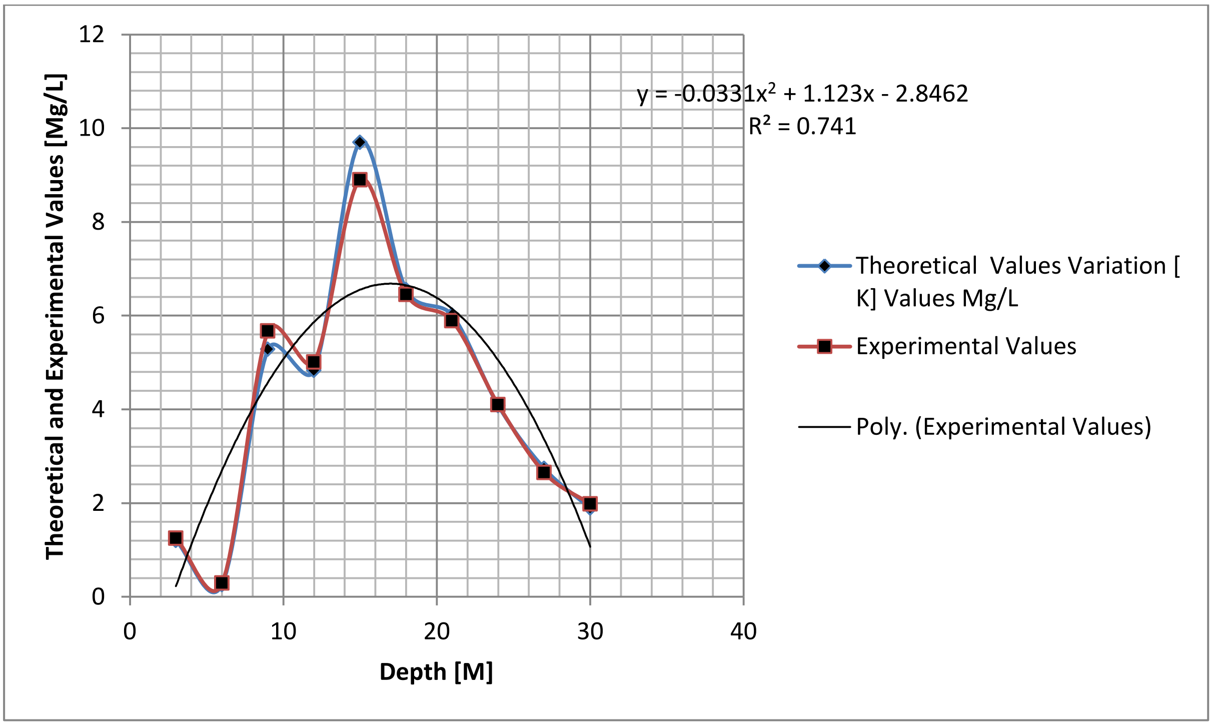

Figure 11: Comparison of Theoretical and Experimental Values Uranium at Different Depths

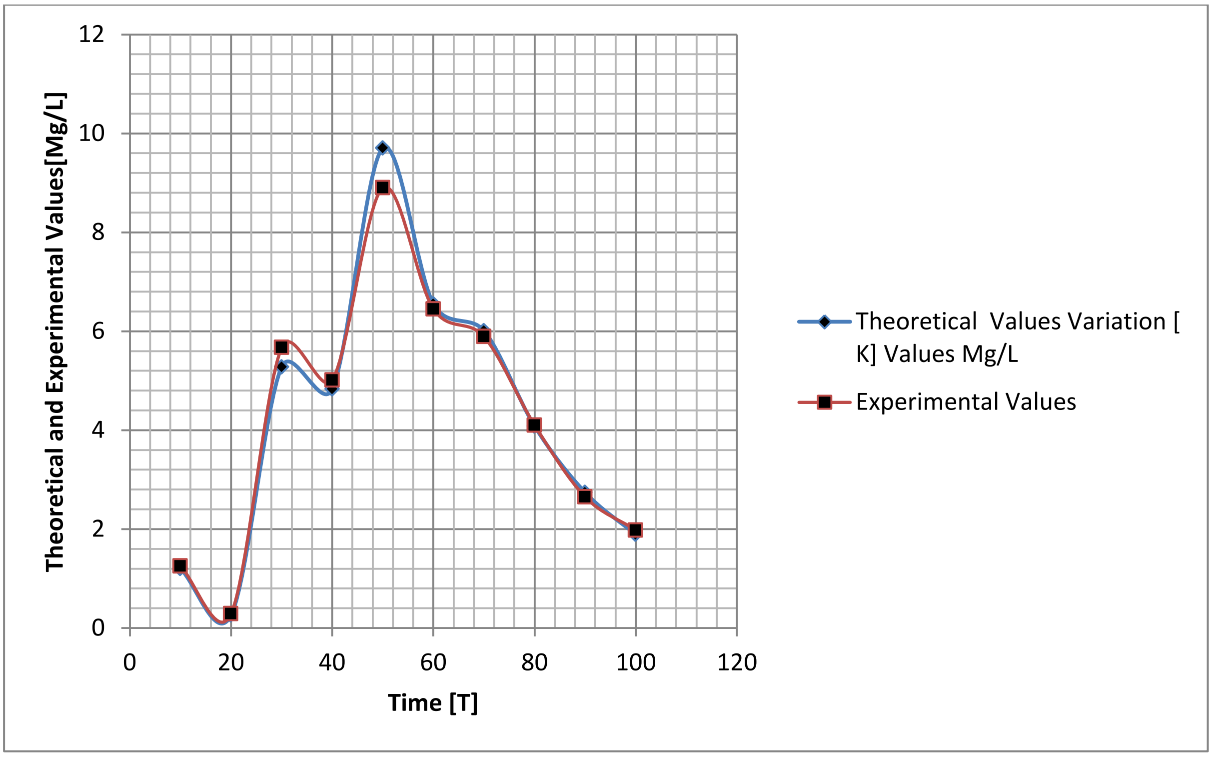

Figure 12: Comparison of Theoretical and Experimental Values Uranium at Different Time

The expression from figure one to seven shows that the system experiences exponential phase as it is expressed in the figure, the theoretical values simulated with constant and different concentrations, the exponential phase experienced in the figure are between the lateritic and silty formation, the theoretical values in the figures that developed exponential phase generated increase in concentration in depths and time at constant and various concentrations, while figure eight to twelve developed a rapid increase in concentrations at eighteen metre at the period of sixty days, it suddenly experiences decrease in fluctuation at different depths between lateritic and silty formation, the result expressed in the figures were compared with experimental values, both parameters compare faviourably well, simulation of the model at different concentration implies that the deposition of uranium may be influenced by other deposited minerals including formation characteristics between the strata. Such conditions were observed in the study through the theoretical model values, validation of the uranium deposition shows the rates of concentration are expressed mathematically in through the derived solution.

4. Conclusion

Modeling and simulation of uranium in lateritic and silty formation were carried out to mathematically represent the behaviour of the microbes between the lateritic and silty formation, the study was to predict through this developed model, the rate of concentration between the lateritic and silty formation express it in various deposition in the system, the developed model were validated with experimental values that established the effectiveness of the model in the study area. The rate of uranium deposition expressed in the figures can be attributed to the regeneration of uranium through industrial settlement in the study area, although there are natural origin depositor in the study area, but the stratification influences developed higher deposition of uranium at various formation in the figures, while few figures observed fluctuation in the formation, the simulation are at various constant and various velocity concentration in the formations. The developed mathematical model at exponential phase of the system shows the behaviour of uranium under the influences of formation characteristics in the study area, the deposition of permeability at high degree influences the migration of uranium as it is expressed in the figure above.

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