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Research article

PREDICTIVE MODEL TO MONITOR EXPONENTIAL PHASE OF URANIUM TANSPORT IN LATERITIC AND SILTY FORMATION AT TRANS-AMADI DISTRICT OF PORT HARCOURT METROPOLIS, NIGER DELTA OF NIGERIA

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Abstract

Predictive model to monitor exponential phase of uranium has been expressed. The model was generated from developed simulated model on exponential phase of uranium deposition in the study area. The simulated model produced an equations that were also resolved to produced theoretical values, this model were compared with column experimental values, both parameters generated a best fit thus validate the predictive values, the expressed values in the figure establish the behaviour of uranium in the transport system , exponential deposition were experienced in figure one while two and three observed fluctuation in there deposition, slight inhibition were observed by microelements in figure two and three, but the deposition of uranium are at high concentration, this implies that the study area are polluted by uranium deposition between lateritic and silty formation , the study is imperative because experts in the field will use this predictive model to monitor and prevent further migration of this substance in the study location.

Keywords: predictive, Model exponential phase, uranium transport, lateritic and silty formation.

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1. Introduction

Indicator organisms are frequently used in place of disease causing pathogens because their presence is indicative of pathogen presence and indicator organisms are easier to detect. Another reason for using simple indicator tests is that pollution is often irregular. It is better to monitor drinking water frequently by means of a simple test than occasionally using more complicated direct pathogen detection tests. Indicator organisms, however, are not universal. Many studies have shown that while traditional indicators may have worked for developed countries in temperate climates, they are not necessarily appropriate for developing countries in tropical environments. There is a need to investigate the suitability of these indicators for their use in tropical environments for the detection of recent fecal contamination in drinking water supplies. Extensive research has already been carried out in this area. These indicators have different characteristics and their significance to the microbial quality of drinking water can vary depending on the monitoring region. After the most appropriate indicator organisms are identified, the methods for their detection are assessed and compared. There is a wide variety of methods available for testing the microbial quality of drinking water through indicator organisms. The two most common methods that are studied in detail in this thesis are the Presence/Absence (P/A) test and Membrane Filtration (MF) test. The P/A test is a simple method to identify the presence or absence of the indicator organism and is often indicated by a color change. While the P/A test may be adequate for detecting the presence of indicator organisms, it is unable to assess the extent of contamination in the water sample. The ability to enumerate indicator organisms is particularly important when assessing the performance of a water treatment device such as a water filter. It allows the researcher to calculate microbial removal efficiency by finding out how much of the indicator organisms are removed by the filter (Eluozo and. Afiibor 2013).

Since the quality of the water supply is often variable and cannot be adequately controlled for millions of people in developing countries, one viable approach could be the implementation of simple, low-cost point-of-use (POU) treatment systems to ensure the provision of safe water for consumption. Point-of-use treatment systems refer to the treatment of water at the household level as opposed to centralized, larger capacity municipal or private systems that carry out treatment of water for a larger population. While an advanced large-scale water treatment system is able to supply many households at any one time, a simple and affordable household water treatment system will be able to reach even the most rural areas of developing countries such as Nepal, therefore reducing their dependency on unsafe drinking water supplies. A good POU system should also satisfy the criteria of requiring minimum training and being easily and cheaply maintained. According to WHO, not all potential waterborne human pathogens are of equal public health significance. Some of them present a serious risk of disease whenever they are consumed in drinking water and are given high priority for health significance. Examples include strains of *Escherichia coli, Salmonella, Shigella, Vibrio cholerae, Yersinia enterocolitica,* and *Campylobacter jejuni*. On the other hand, some organisms may cause disease .opportunistically.. These organisms cause infection mainly among people with impaired natural defense mechanisms. These people include the very old, the very young, Immunocompromised people, and patients in hospitals. Examples of these organisms include *Pseudomonas, Klebsiella,* and *Legionella* (WHO, 1996). For pathogens of fecal origin, drinking water is the main route of transmission. Unhygienic practices

during the handling of food, utensils and clothing also play an important role. Humans are typically the main carriers of large populations of these bacteria, protozoa, and viruses (WHO, 1996). Pathogens originating from human sources, often from human feces, are called .enteric. (of intestinal origin) pathogens. An example is *E.coli* O157:H7 (Eluozo and. Afiibor,2013). The intestine of many domestic and wild animals, their meat, milk and dairy products, are sources of the bacteria *Yersinia enterocolitica* and *Campylobacter* (WHO, 1996). The persistence of a pathogen in water also affects their transmission to humans. A more persistent pathogen that can survive longer outside the host body is more likely to be transmitted to other people. Bacteria are single-celled prokaryotes (without nucleus) with sizes ranging from 0.3 to 100 micrometers (μm) in length (Metcalf and Eddy, 1991Eluozo and.Afiibor, 2013)).
Therefore, these organisms can survive for long periods in water habitats (WHO, 1996). *Shigella*, also part of Enterobacteriaceae, causes dysentery in humans and is usually transmitted through direct contact. Other bacteria species of significance but not part of this family include the following: *Vibrio cholerae,* specifically the serogroups O1, causes cholera, an acute intestinal disease with massive diarrhea, vomiting, dehydration, possibly leading to death. Some other pathogenic bacteria include *Campylobacter* and opportunistic pathogens such as *Legionella pneumophila* and *Aeromonas E.coli* are characterized by their ability to produce potent .Enterotoxins.. Enterotoxins are similar to hormones which act on the small intestine, causing massive secretion of fluids which lead to the symptoms of diarrhea (Madigan et al., 2000, Chian, 2001). Another important protozoan, the *Cryptosporidium* species, also causes diarrhea. Specifically, *C. parvum* is the major species causing the disease. Human beings are the reservoir for these infectious protozoa's and one infected human can excrete 109 oocysts a day. *C. parvum* oocysts are 4 to 6 μm in size and spherical in shape. Similar to *Giardia* cysts, *C. parvum* oocysts can survive for several months in water at 4ºC and are highly resistant to chlorine. *C. parvum* also has a low infective dose. The disease was produced in two primates when they were given a dose of only 10 oocysts (Miller et al., 1990). While these indicator bacteria or viruses are not necessarily pathogenic themselves, some of them have the same fecal source as the pathogenic bacteria and can therefore indicate fecal contamination of water (WHO, 1993a). One example which fulfils many of the above criteria is the indicator organism *E.coli*. Therefore, it may be sufficient to get an indication of the presence of pathogens of fecal origin with the detection and enumeration of *E.coli*. Such a substitution is especially valuable when resources for microbiological examination are limited as in Nepal or other developing countries the disposal of municipal solid waste (MSW) has the potential to impact the environment negatively. The main concern is to prevent the contamination of soil and water by the leachates that originates in the decomposition of the solid waste inside landfills (Kjeldsen et al., 2002). The volume and chemical composition of leachates depends on the water that infiltrates in the landfill, and on the chemical reactions between the solid and liquid phases, including dissolution, precipitation, ion exchange and biochemical processes. Leachates migration from inside the landfill cell to the vadose zone is prevented by low permeability liners (Petrov and Rowe, 1997; Guyonnet et al., 2005; Touze-Foltz et al., 2006 Francisca, 2010), which usually have multiple layers of compacted clay, granular filters and geosynthetics. Compacted clays or mixtures of local soils with clay are frequently used to achieve very low hydraulic conductivity barriers and prevent subsurface contamination. The hydraulic conductivity can be further reduced by the addition of Bentonite to local soils to attain the values specified by international regulations (kb10−7 cm/s) (Kayabali, 1997; Goldman et al., 1998). The ability of compacted soil liners to restrict the

movement of water and contaminants depends on particle size, void ratio, specific surface, degree of saturation, and fluid properties (Vukovid and Soro, 1992; Foged and Baumann, 1999). Soil fabric, compaction energy and thixotropy are also relevant properties (Daniel and Benson, 1990; Benson and Trast, 1995). Different particle associations created during compaction generate either flocculated or dispersed soil fabrics, and are of fundamental importance in the soil hydraulic conductivity (Mitchell et al., 1965). In the past two decades, several studies were conducted to evaluate how soil and liquid properties control the hydraulic conductivity of soil liners (Mitchell et al., 1965; Mitchell and Jaber, 1990; Gleason et al., 1997; Schmitz, 2006). In general, the hydraulic conductivity of soils decreases with increasing fine particle content (Sivapullaiah et al., 2000). At high mechanical stress levels and in the case of highly compacted soils, electrical forces have negligible effect on soil behavior and soil fabric is slightly affected by the chemical properties of the permeating liquid (Mitchell and Soga, 2005). However, hydraulic behavior of fine soils with high porosity and freshly compacted soils is highly influenced by the interaction between the pore fluid and mineral particles.

2. Materials and method

Soil samples from several different borehole locations, were collected at intervals of three metres each (3m). 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 soil formation, the result were analysed to determine the rate of uranium concentration between lateritic and silty formation through column experiment in the study area.

3. Theoretical Background

Theoretical background for 3rd degree polynomial curve fitting

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

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

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

$y_2 = a_0 + a_1 x_2 + a_2 x_2^2 + a_3 x_2^2 + \dots\dots\dots + a_n x_2^n \dots$ ………… (2)

$y_3 = a_0 + a_1 x_3 + a_2 x_3^2 + a_3 x_2^2 + \dots\dots\dots + a_n x_2^n$ ………… (3)

$y_4 = a_0 + a_1 x_4 + a_2 x_n^2 + a_3 x_n^2 + \dots\dots\dots + a_n x_4^n$ ………… (4)

Summing all the equations will yield (1 n) $\rightarrow$

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

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

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

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

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

Multiply equation (6) by x_i

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

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

Multiply equation (6) by x_i^2

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

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

Multiply equation (3.85) by x_i^3

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

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

Multiply equation (6) by x_i^n

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

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

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:

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 \qquad 11$$

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

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

4. Results and discussion

Predictive values and experimental values that represent the behaviour of the system are presented in tables and figure below.

Table: 1 Comparison of Theoretical and Experimental Values of Uranium at Different Depths

Depths [m]	Predictive Values	Experimental values
3	1.19	1.25
6	4.74	4.88
9	10.61	10.44
12	18.81	18.55

15	**29.32**	**31.22**
18	**42.16**	**43.11**
21	**57.32**	**58.11**
24	**74.8**	**75.11**
27	**94.61**	**95.11**
30	**116.73**	**117.1**

Table: 2 Comparisons of Theoretical and Experimental Values of Uranium at Different Depths

Depths [m]	Predictive Values	Experimental values
3	0.025	0.031
6	2.64	2.56
9	10.61	11.11
12	6.4	6.19
15	6.82	6.67
18	7	7.22
21	6.55	6.34
24	5.51	5.43
27	3.84	3.55
30	1.56	1.42

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

Depths [m]	Predictive Values	Experimental values
3	0.22	0.32
6	2.7	2.5
9	4.58	4.33
12	5.87	5.67
15	6.57	6.44
18	6.67	6.33
21	6.18	6.11
24	5.1	5.23
27	3.42	3.22
30	1.14	1.11

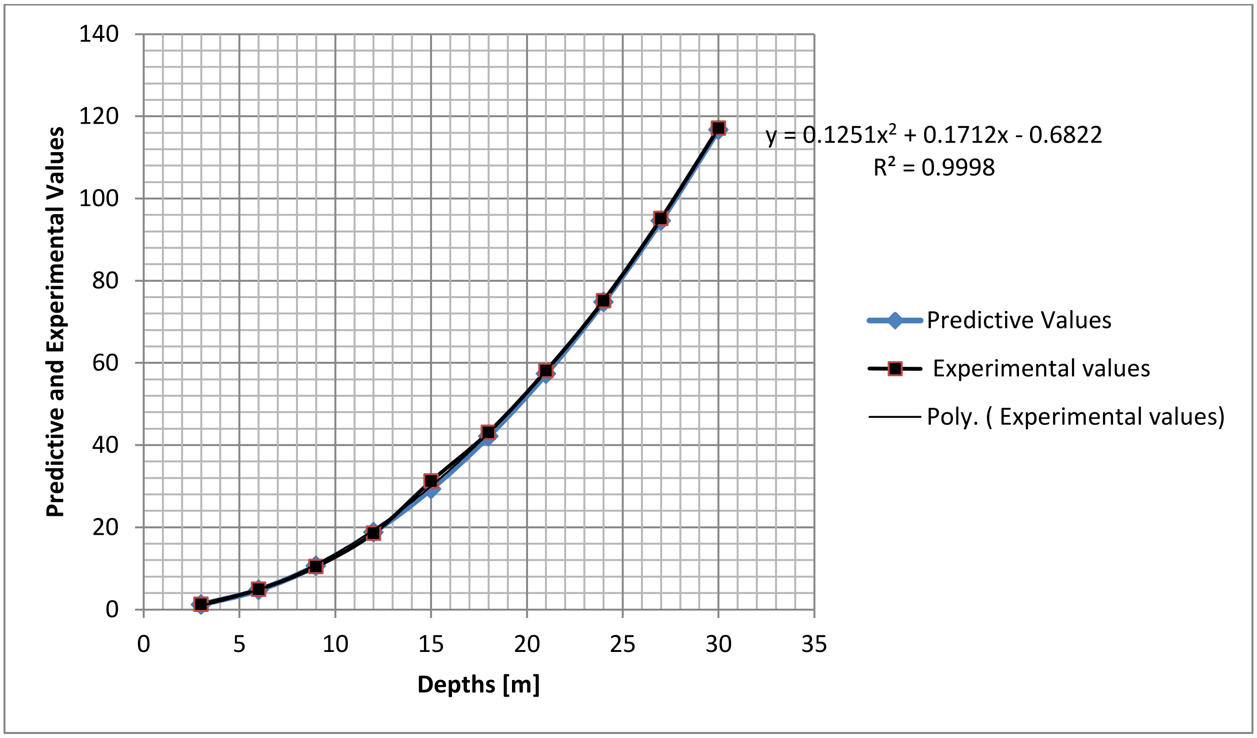

Figure: 1 Comparison of Theoretical and Experimental Values of Uranium at Different Depths

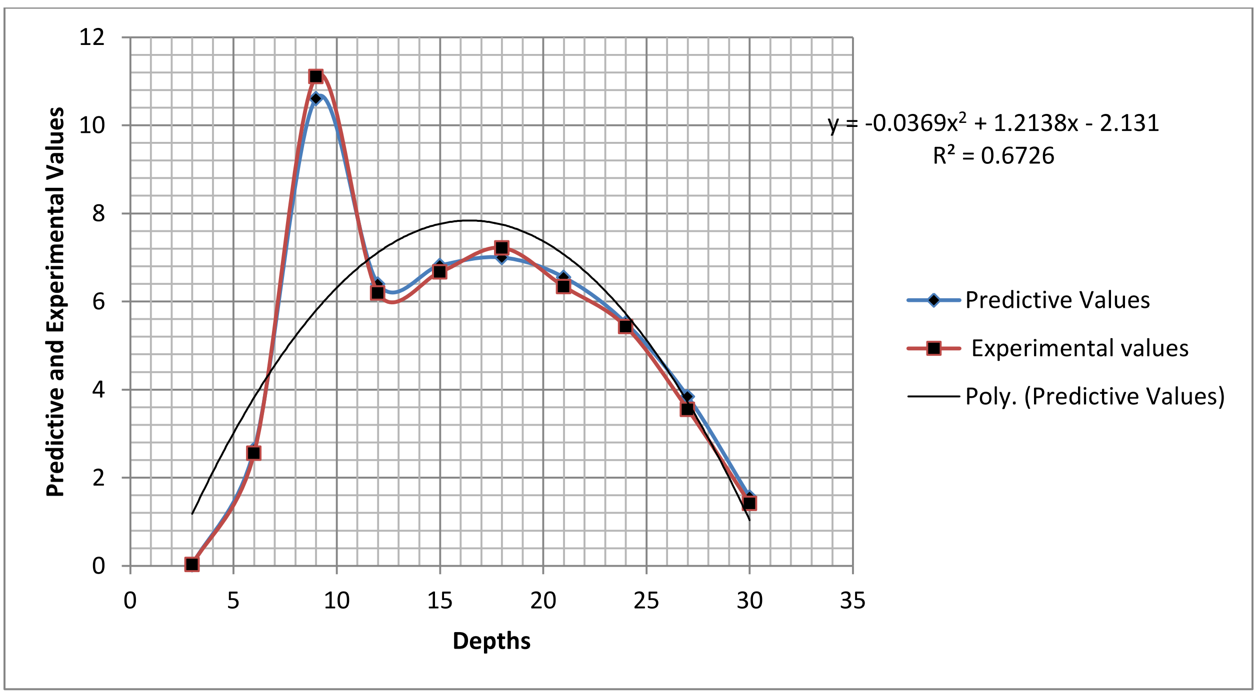

Figure: 2 Comparisons of Theoretical and Experimental Values of Uranium at Different Depths

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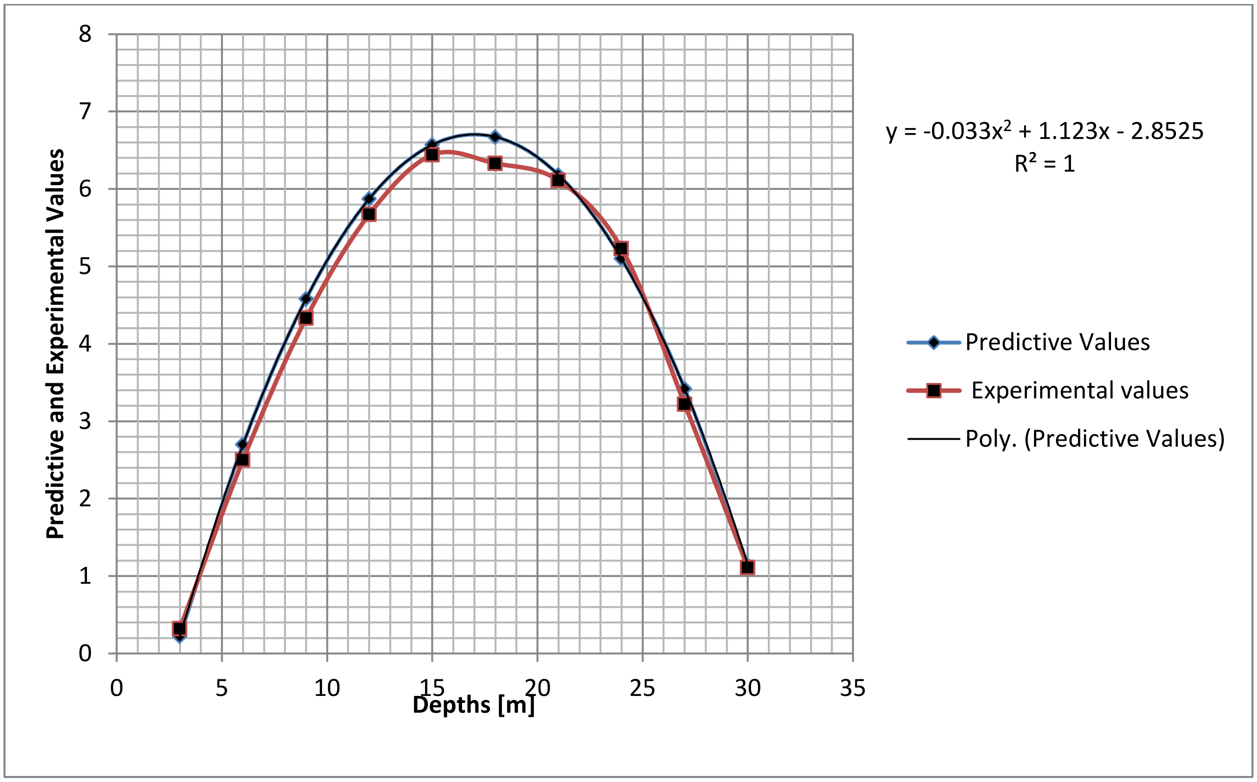

Figure: 3 Comparisons of Theoretical and Experimental Values of Uranium at Different Depths

The figure one shows that the depositions of uranium are in progressive phase on the transport process, the lowest were recorded at three metres and rapidly increase to the optimum value at thirty metres, this implies that the substances in environment are deposited in where the migration process are at ease without any hindrances as expressed in the figure presented. Figure two developed similar condition by rapidly increase from three to nine metres, sudden decrease were experienced between nine and twelve metres, but at fifthteen metres gradual process of decreasing were finally observed were the lowest concentration of uranium were recorded at thirty metres. Figure three established a gradual increase to the optimum value observed at eighteen metres, gradual decreases were experienced from twenty one to thirty metres. All the expressed figures are theoretical values from the simulated model at exponential phase of the transport process, it is compared with experimental values and both parameters generated best fit to validate the predictive results in the study location, two figures that experience decrease on the transport process are base on the inhibition from microelements that may have deposited in exponential condition in those region of the formation, although porosity were experienced at the silty zone of the strata, but it is low degree still made degradation of uranium concentration insignificant in the formation.

4. Conclusion

Uranium deposition at exponential phase has been express through developed theoretical values the expressed parameters were compared with experimental results in the formations, both parameters generated best fit showing the validation of the developed predictive values, the values were found to experiences increase in concentration with respect to change in depths, several influences developed rapid increase at figure one and fluctuation experiences in figure two and three respectively. The developed figures expressed different behaviour of the substance deposition at different formations, the migration process are also influenced by formation characteristics such as permeability of the strata, they are deposited at different degree, but even at this condition generally, the degree of permeability developed low deposition between the silty zone formation, this condition produced high concentration if not for experienced inhibitions from microelements in the study location. The study is imperative because experts will applied this concept to monitor the concentration of the uranium at different formations.

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