World Essays Journal / 10 (1): 1-8, 2022
Available online at www. worldessaysj.com
ISSN online: 2310-1377, Print: 2310-8509

Transport Effect from Degree of Saturation on Accumulation of Chromium in Lateritic and Siltyclay Formation

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Paper Information

Received: 19 November, 2021

Accepted: 28 January, 2022

Published: 20 March, 2022

ABSTRACT

Chromium deposition pressured by degree of saturation were monitored applying deterministic modelling techniques, the study express the rate of saturation effect on the migration process of chromium, the developed model were subjected to simulations, the results express various rate of chromium concentration under the influences of various degree of saturation in silty and clay formation, the behaviour of water penetration into soil and its volume content has been describes by experts in various dimensions under the deposition of water content base on several factors, the mechanic of soil has express degree of saturation to affect the rate of chromium concentration when water has filled up the void ratio of the soil, the degree of saturation is one of the formation characteristics which also includes porosity and permeability, these variables also influences where found as determinant of the migration concentration between silty and clay formation in the study area. Gradual and rapid processes of chromium concentration were as a result of these factors deposited in the study as it expressed from the simulation values. Experts will definitely apply these concepts in monitoring this contaminant in such deposited formations.

Key words: *transport, chromium, degree of saturation, silty and clayey formation*

Introduction

The formation of lateritic soils occurs through the pedological alteration processes that act later or together with the mechanisms of disaggregation and decay caused by physical and chemical weathering, with a more intense chemical action. The pedagogical alteration process that contributes most significantly to lateritic soil formation is leaching, which is the intense migration of particles under the action of infiltration and evaporation, resulting in a layer of porous soil (high permeability), consisting of more stable minerals (quartz, kaolinite and magnetite) and a low degree of saturation. Since this process is very slow, it occurs in the well-drained superficial layers, located above the water level, therefore, not saturated [1]. This variable is called suction and can be matric or total. First, in order to evaluate changes in the suction of a stress state in an unsaturated soil, it is necessary to determine the soil-water characteristic curve (SWCC). This curve is a graphical representation of the suction (matric or total) and the quantity of water that can be represented by the gravimetric moisture content (w), volumetric moisture content (θ) or the degree of saturation [11]. SWCC describes a different pathway in terms of soil drying or wetting. Because of this, the curves obtained by the drying or wetting paths do not coincide, giving rise to a phenomenon called curve hysteresis and which is a characteristic of soil suction [2]. Hysteresis caused by drying and wetting paths can be attributed to non-uniformity of the voids, to the air bubbles captured by the voids of the soil during the wetting and structure alteration due to the expansion or contraction of the soil [3]. According [9], the real value of suction depends not only on the degree of saturation, but also on the initial state of the soil and the whole history of drying and wetting until that moment. The test consists of placing a filter paper with its known retention characteristics in a hermetic environment along with a soil sample. Due to the contact of the paper with the soil, which is able to retain moisture content, there is water migration until potential equilibrium is reached, thus obtaining matric suction [7]. If water in the soil is not in direct contact with the filter paper, total suction can be obtained after the potential equilibrium. This equilibrium time is being studied by several authors. [5] Suggests a seven day equilibrium time for suction values above 10,000 kPa and four days for values lower than 10,000 kPa. [7] [Argues that equilibrium time is related to the type and level of suction. This author suggests a seven day period when measuring matric suction, regardless of the level of suction. [1], the minimum equilibrium time between the filter paper and the soil is seven days. Equilibrium time is a very important factor to obtain the correct suction value. The procedure of this method is quite simple; however, it requires great care in determining the filter paper moisture content. [6], filter paper weighing time should be approximately 30 seconds to prevent gains or losses of moisture to the atmosphere. According to [8], the filter paper transfer time for a closed capsule or a zip lock plastic bag must be 5 seconds at most. According to [10], the elimination of the cavitations nucleons demands a special technique that the majority of the commercial tensiometers cannot withstand. To minimize the problem, distilled and de-aired water is used, when the tensiometer saturation is done. Some procedures must be performed with care during the tensiometer saturation and calibration, according to [7 and 8]. The saturation of the porous element can be done by simple immersion, when the porous stone used has capacity of the up to 100kPa of air-entry. However, caution must be taken due to the possibility of air bubbles forming on the walls of the pipe.

Governing Equation

$$Vt\frac{\partial C}{\partial L} = \frac{Vw}{V}\frac{\partial C}{\partial t} + Kt\frac{\partial C}{\partial L} \tag{1a}$$

Nomenclature
Vt = Velocity of flow [LT^{-1}]
$S = \frac{Vw}{V}$ = Degree of saturation [-]
Kt = Permeability [LT^{-1}]
L = Depth
T = Time

Simplifying the expression, let $\frac{Vw}{V}$ denote as τ so that the equation can be written as:

$$Vt\frac{\partial C}{\partial L} = \tau\frac{\partial C}{\partial L} + Kt\frac{\partial C}{\partial L} \tag{1b}$$

$$Vt\frac{\partial C}{\partial L} - \frac{\partial C}{\partial t} = \frac{\partial C}{\partial t} + \tau + Kt \tag{2}$$

$$(Vt-1)\frac{\partial C}{\partial L} = \frac{\partial C}{\partial L} + \tau + K \tag{3}$$

$$(Vt-1)\frac{\partial C}{\partial L} = \frac{\partial C}{\partial t} \tag{4}$$

$$0 = \frac{\partial C}{\partial L} + \tau + K \tag{5}$$

i.e. $$\frac{\partial C}{\partial t} = -\tau - Kt \tag{6}$$

From (5) integrate directly, we have

$$C = (-\tau - Kt)t + S_1 \tag{7}$$

From (6)

$$\frac{\partial C}{\partial L} = \frac{\partial C}{\partial t}$$

Let $$C = LT \tag{8}$$

$$\frac{\partial C}{\partial L} = Z^1 T \tag{9}$$

$$\frac{\partial C}{\partial L} = ZT^1 \tag{10}$$

Substitute (9) and (10) into (3), we have

$$(Vt-1)Z^1 T = (\tau - Kt)ZT^1 \tag{11}$$

$$(Vt-1)\frac{Z^1}{Z} = (\tau - Kt)\frac{T^1}{T} = \phi \tag{12}$$

$$(Vt-1)\frac{Z^1}{Z} = \phi \qquad (13)$$

$$(\tau - Kt)\frac{T^1}{T} = \phi \qquad (14)$$

From (13) $\frac{Z^1}{Z} = \frac{\phi}{(Vt-1)} z$

$$Ln\, Z = \frac{\phi}{(Vt-1)} z + S_2 \qquad (16)$$

$$Z = A\ell^{\frac{\phi}{(Vt-1)} z} \qquad (17)$$

From (14)

$$(\tau + Kt)\frac{T}{T} = \phi$$

$$T = \frac{\phi}{(\tau + Kt)} \qquad (18)$$

$$Ln\ T = \frac{\phi}{(\tau + Kt)} t + S_3 \qquad (19)$$

$$T = B\ell^{\frac{\phi}{\tau + Kt} t} \qquad (20)$$

Put (17) and (20) into (8), yield

$$C_2 = A\ell^{\frac{\phi}{(Vt-1)} z} \bullet B\ell^{\frac{\phi}{\tau + Kt} t} \qquad 21)$$

$$C_2 = AB\ell\left(\frac{z}{(Vt-1)} + \frac{t}{\tau + Kt}\right)^{\phi} \qquad (22)$$

Hence general solution becomes:

$$C\,[LT] = S_1 + S_2$$

$$C\,[LT] = AB\ell\left(\frac{z}{(Vt-1)} + \frac{t}{\tau + Kt}\right)^{\phi}$$

Materials and method

Standard laboratory experiment where performed to monitor the degree of saturation different formation, the soil deposition of the strata were collected in sequences base on the structural deposition at different locations, this samples collected at different location generate variation at different depth producing different migration of salmonella concentration through pressure flow at different strata, the experimental result are applied to compare with the theoretical values to determined the validation of the model.

Result and Discussion

Results and discussion are presented in tables including graphical representation of salmonella concentration

Table: 1 Degree of Saturation at Different Depth

Depth[m]	Predictive Chromium conc.
3	1.14E-03
6	1.37E-03
9	1.77E-03
12	2.44E-03
15	2.55E-03
18	3.63E-03
21	4.35E-03
24	5.45E-03
27	6.78E-03
30	8.55E-03
33	1.23E-02
36	3.77E-02

Table: 2 Degree of Saturation at Different Time

Time	Predictive Chromium conc.
10	1.14E-03
20	1.37E-03
30	1.77E-03
40	2.44E-03
50	2.55E-03
60	3.63E-03
70	4.35E-03
80	5.45E-03
90	6.78E-03
100	8.55E-03
110	1.23E-02
120	3.77E-02

Table: 3 Comparisons of Predicted and Experimental Values at Different Depths

Depth[m]	Predictive Chromium conc.	Experimental Chromium conc.
3	1.14E-03	1.28E-03
6	1.37E-03	1.51E-03
9	1.77E-03	1.68E-03
12	2.44E-03	2.35E-03
15	2.55E-03	2.67E-03
18	3.63E-03	3.55E-03
21	4.35E-03	4.65E-03
24	5.45E-03	5.65E-03
27	6.78E-03	6.81E-03
30	8.55E-03	8.65E-03
33	1.23E-02	1.39E-02
36	3.77E-02	3.87E-02

Table: 4 Comparisons of Predicted and Experimental chromium Values at Different Times

Time	Predictive Chromium conc.	Experimental Chromium conc.
10	1.22E-03	1.35E-03
20	1.45E-03	1.62E-03
30	1.77E-03	1.96E-03
40	2.34E-03	2.34E-03
50	2.75E-03	2.78E-03
60	3.45E-03	3.67E-03
70	4.47E-03	4.54E-03
80	5.57E-03	5.66E-03
90	6.80E-03	6.89E-03
100	8.55E-03	8.76E-03
110	1.30E-02	1.34E-02
120	3.66E-02	3.76E-02

Table: 5 predictive values of chromium concentration at Different Depth

Depth[m]	Predictive Chromium conc.
3	2.57E+00
6	3.23E+00
9	3.88E+00
12	5.23E+00
15	6.57E+00
18	7.88E+00
21	9.88E+00
24	1.50E+01
27	1.74E+01
30	1.95E+01
33	2.73E+01
36	3.54E+01

Table: 6 Degree of Saturation at Different Time

Time	Predictive Chromium conc.
10	2.57E+00
20	3.23E+00
30	3.88E+00
40	5.23E+00
50	6.57E+00
60	7.88E+00
70	9.88E+00
80	1.50E+01
90	1.74E+01
100	1.95E+01
110	2.73E+01
120	3.54E+01

Table: 7 Comparisons of Predicted and Experimental Values at Different Depth

Depth[m]	Predicted Chromium conc.	Experimental Chromium conc.
3	2.57E+00	2.65
6	3.23E+00	3.43
9	3.88E+00	4.21
12	5.23E+00	5.34
15	6.57E+00	6.66
18	7.88E+00	7.88
21	9.88E+00	9.92
24	1.50E+01	13.23
27	1.74E+01	16.34
30	1.95E+01	20.33
33	2.73E+01	29.64
36	3.54E+01	33.56

Table: 8 Comparisons of Predicted and Experimental Values at Different Times

Time	Predicted Degree of sat	Experimental Degree of sat
10	2.57E+00	2.52
20	3.23E+00	3.31
30	3.88E+00	4.33
40	5.23E+00	5.34
50	6.57E+00	6.64
60	7.88E+00	7.44
70	9.88E+00	9.92
80	1.50E+01	13.34
90	1.74E+01	16.51
100	1.95E+01	20.34
110	2.73E+01	29.63
120	3.54E+01	33.51

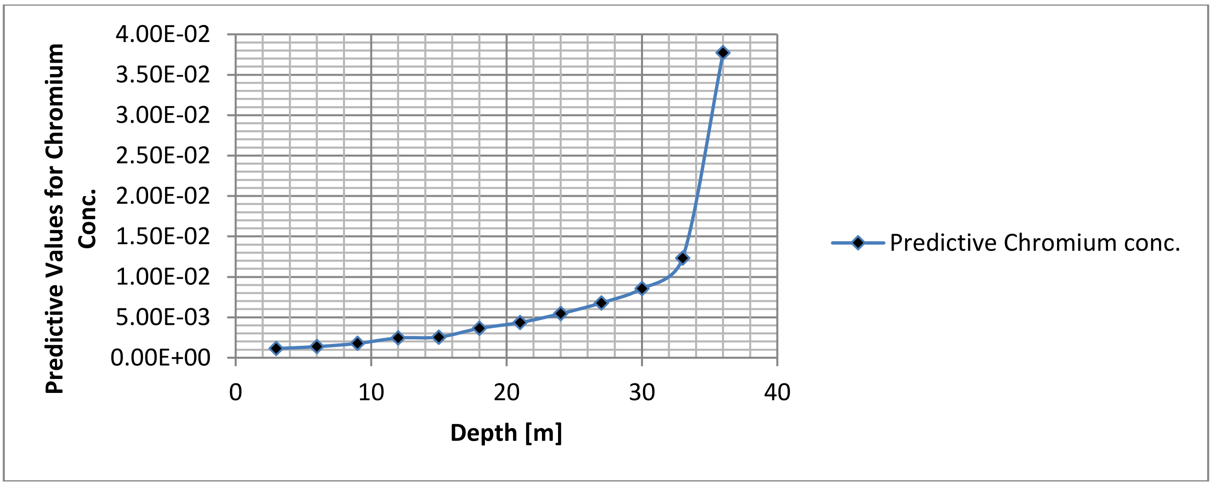

Figure1: Predictive Values for Chromium Concentration at Different Depth

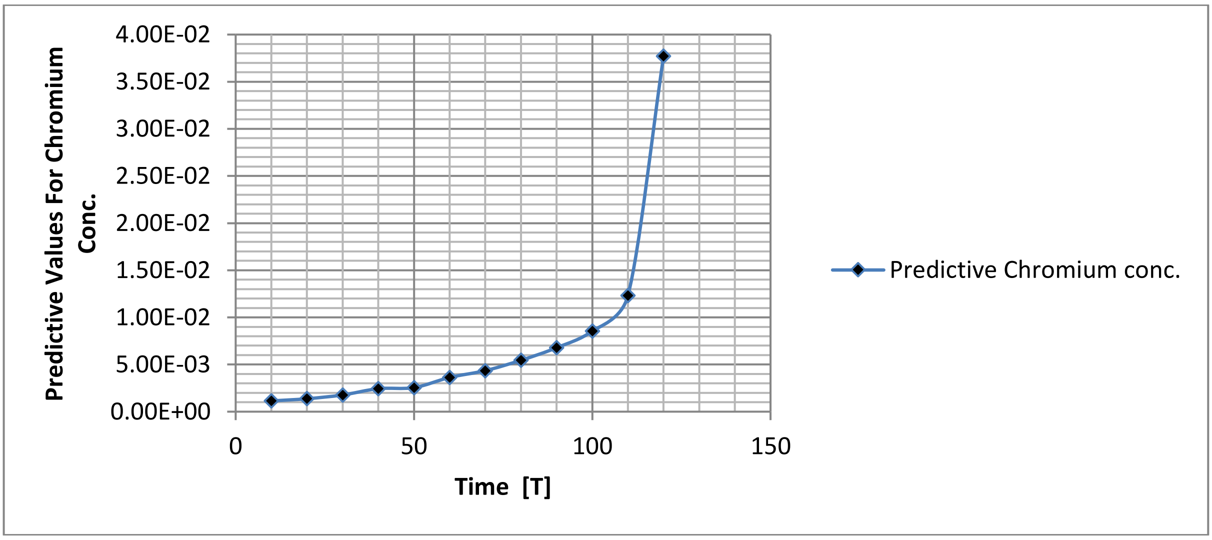

Figure 2: Predictive Values for Chromium Concentration at Time

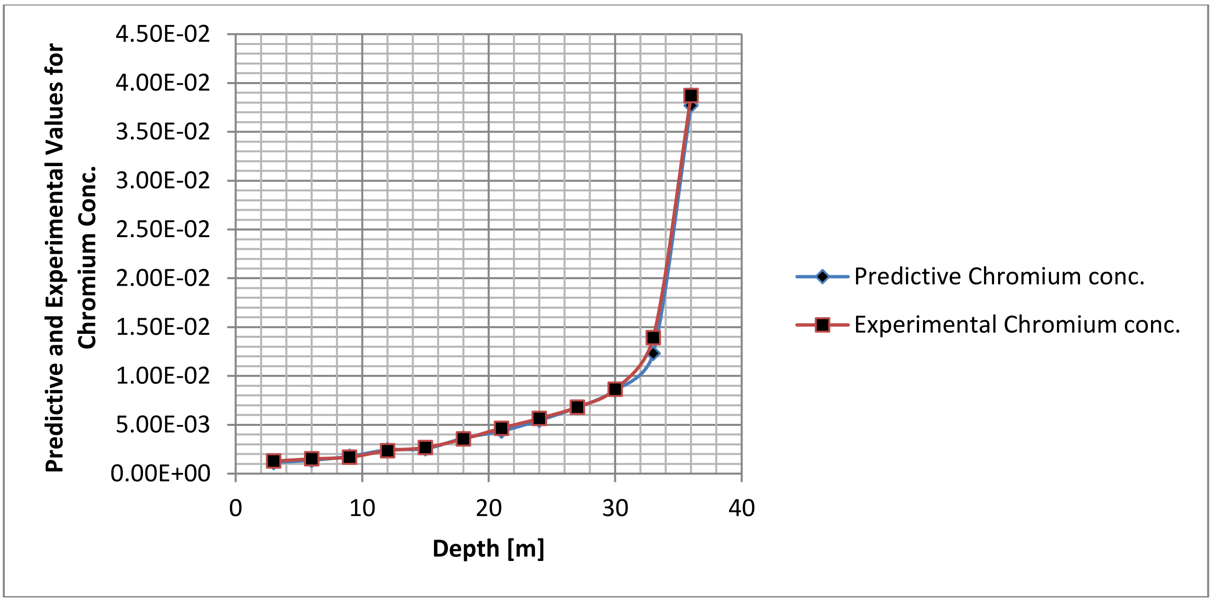

Figure 3: Predicted and Experimental Values for Chromium Concentration Values at Different Depth

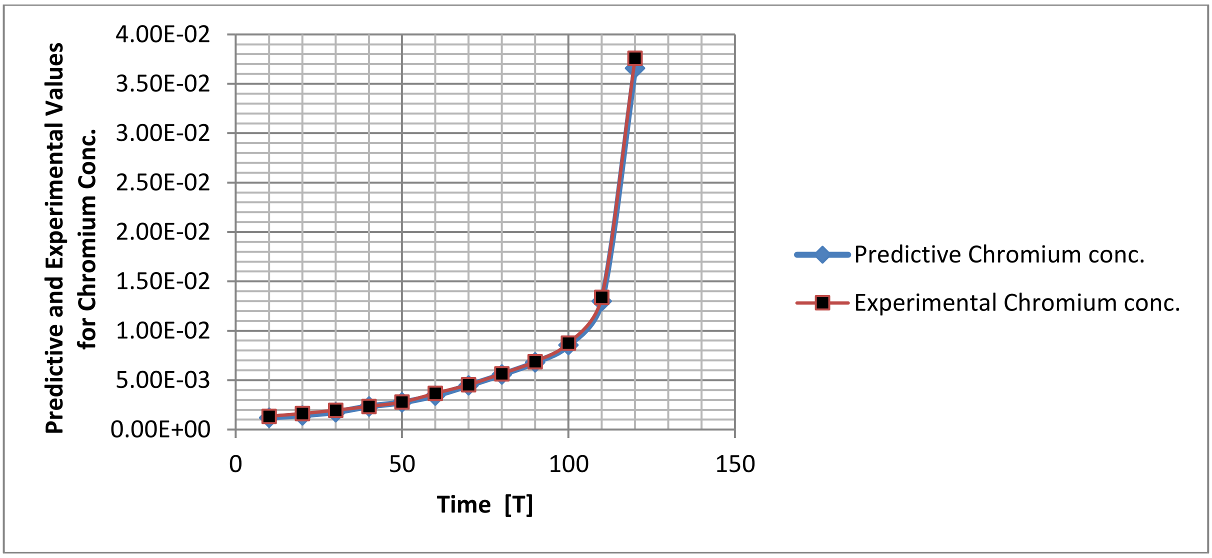

Figure 4: Predicted and Experimental Values for Chromium Concentration Values at Different Depth

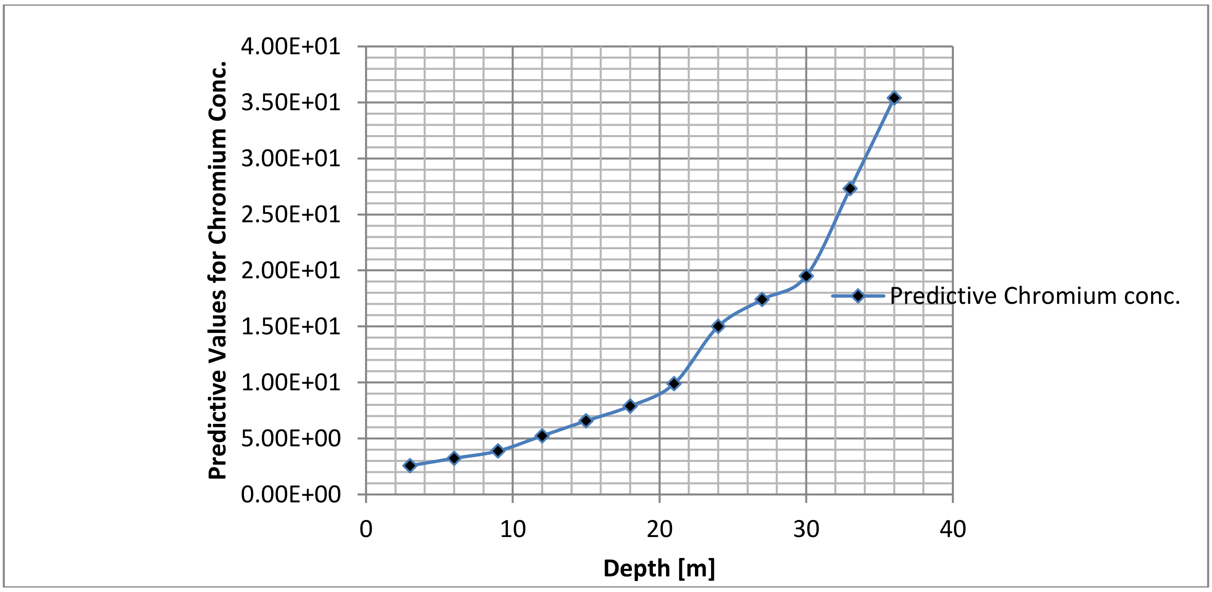

Figure 5: Predictive Values for Chromium Concentration at Time

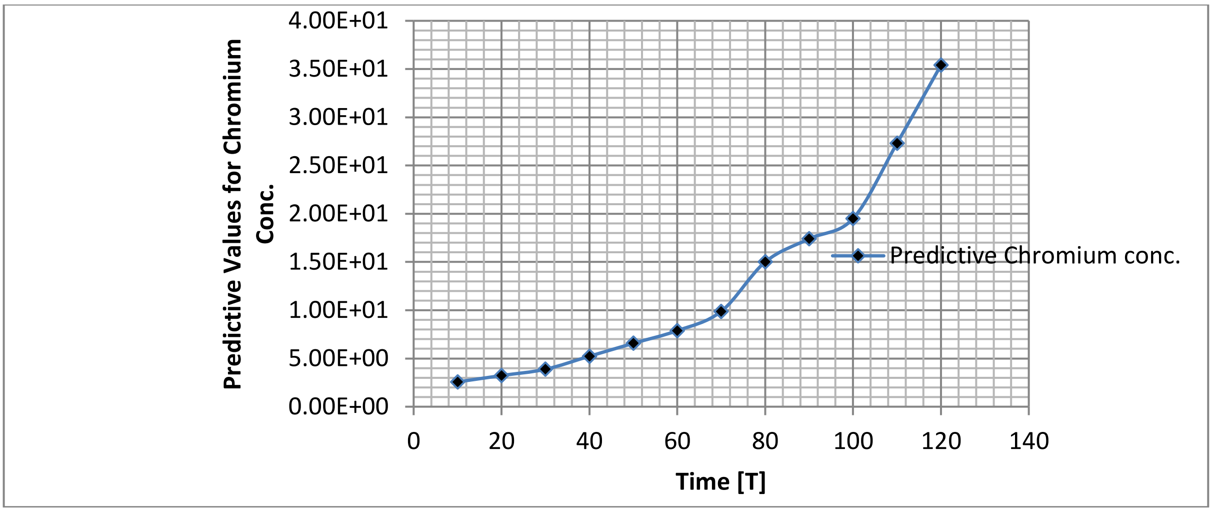

Figure 6: Predictive Values for Chromium Concentration at Time

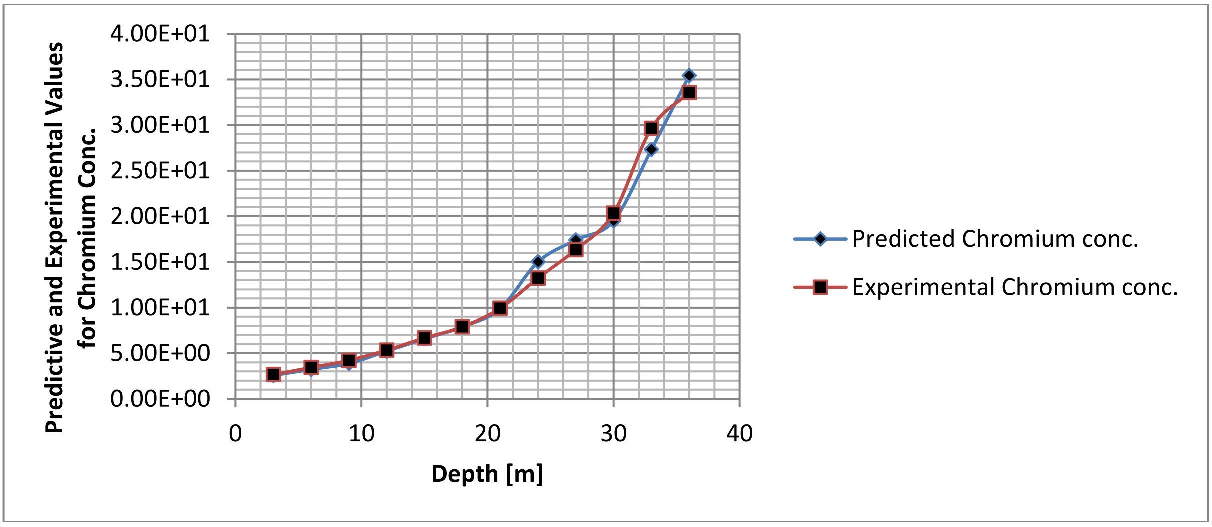

Figure 8: Predicted and Experimental Values for Chromium Concentration Values at Different Depth

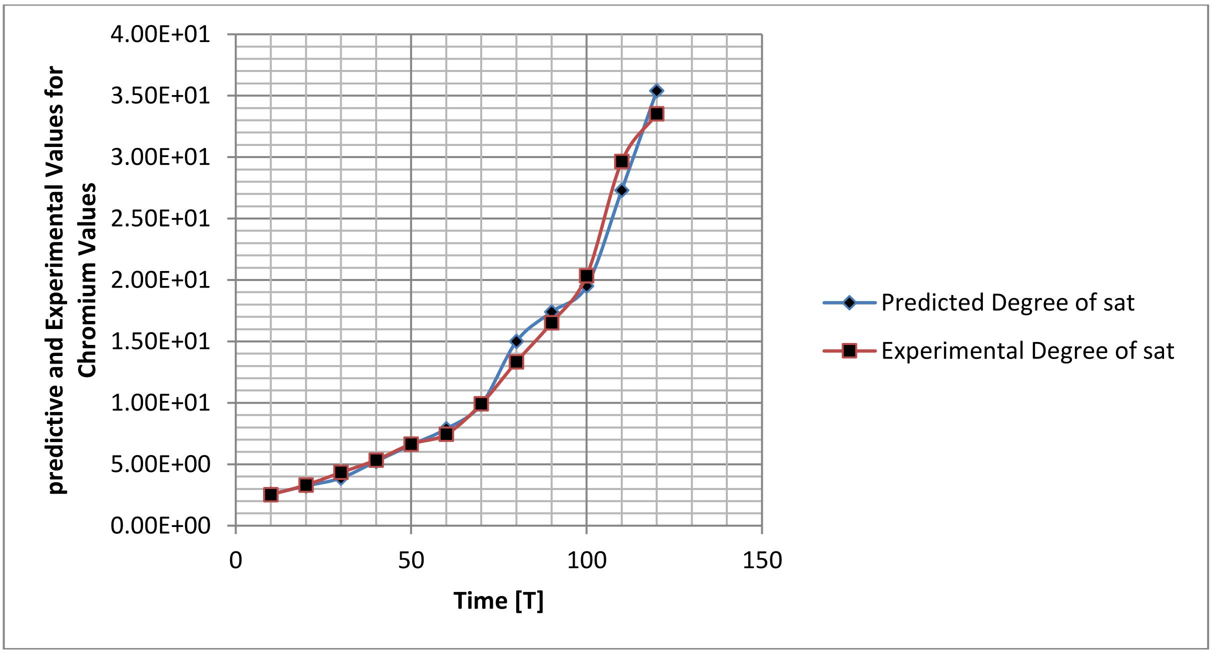

Figure 8: Predicted and Experimental Values for Chromium Concentration Values at Different Depth

The study has definitely expresses how degree of saturation affect the deposition of chromium content in silty and clay formation. From figure one to four exponential rate of concentration where observed with respect to depth and time of transport process, the rate of saturation in the soil influences the migration process of chromium in the study area, because the deposition of silty and clay formation developed slow migration from three to thirty three metres, these are were transition zone of silty formation pressured rapid increase of the substances to the optimum level at thirty six metre at the period of one hundred and twenty days. Comparison between predictive and experimental values developed best fits for figure three and four. While figure five to eight developed slight vacillation with predominant exponential phase to the optimum level recorded at thirty six metres at the period of one hundred and twenty days, this show how the behaviour of soil through increase in moisture content pressure the microbes under exponential condition, these condition implies that the soil deposit fluctuation on the degree of saturation experiencing reflecting on the concentration rate of chromium. more so the formation in the study location displayed low degree of saturation base on volume of void between the intercedes of soil formation, low degree of saturation may be as a results of the level temperature, the rate of porosity and permeability, it may also determine deposition of saturation content of the soil base on their various degrees. These conditions were monitored to determine the rate of effect of saturation that pressures the migration rate of chromium in the study location. Furthermore, it was also observed that figure five to eight express high deposition of degree of saturation in silt clayey formation, the express figure shows that the silty clayed formation may deposit more percent of degree of saturation at these formations, deltaic predominance’s influences were observed at the location of the soil, permeability and porosity including void ratio were experiences to deposit low percentage, pore distribution are very low, these resulted to volumetric water content observed to deposit high degree, the Water Content Significantly affects properties of Silt and Clayey soils (unlike sand and gravel). Plasticity property describes the response of a soil to change in moisture content. These expression are the pressured from formation that deposit in silty and clay formation, Strength decreases as water content increases–Soils swell-up when water content increases. Fine-grained soils at very a high water content possess properties similar to liquids. As the water content is reduced, the volume of the soil decreases and the soils become plastic develop accumulation of the substances in some strata, if the water content is further reduced, the soil becomes semi-solid when the volume does not change.

Conclusion

The study has express the level of effect from degree of saturation on the migration rate of chromium through the developed model. it has also expressed various degree of saturation in different deposition of the soil reflecting on the transport process thus concentration rate of chromium at different strata. The simulation values shows various degree of saturation cause by several factors on the influences on chromium depositions in silty and clay formation, the degree of saturation were found to be influenced by low deposition of void ratio between the intercedes of the formation developing accumulation in shallow strata in the study location, these were monitored with respect to depth and time of migration from the simulation. these implies that those location that degree of saturation are very low shows that the porosity and void rate of percentage are very low, these also implies that permeability in those region may experiences low degrees . Other location that observed high degree of saturation; these are formation were high degree of porosity permeability and void ratio experiences high deposited content, deltaic influences were observed to have predominantly pressure higher concentration of chromium in the study area.

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