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Research article

MODELING AND SIMULATION OF CADMIUM DEPOSITION IN HOMOGENEOUS SILTY FORMATION, RUMUOKWUTA DISTRICT OF PORT HARCOURT METROPOLIS, NIGER DELTA OF NIGERIA

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Abstract

Modeling and simulation of cadmium has express the rates of its hazard in soil and water environment, the study was to ensure that the deposition and migration of cadmium are thorough monitored since it has generated lots of hazards in soil and water environments, such development call for serious concern, due it unhealthy implications in the study environment, predominant formation characteristics were observed to pressure the migration of cadmium, high degree of void ratio deposited in the strata generate fast migration of the substances in soil formations, development of mathematical model were found appropriate to monitor the rate of concentration with respect to change in depth at homogeneous formation, it was also observed within a period of hundred days at thirty metres deep to produce higher concentration, the depositions varies at different strata since the geological setting express some significant variations on the void ratio of the soil. The concentration experienced rapid migration at progressive phase condition, this situation are pressured by the stratification setting of the study environment, experts will find this model faviourable because it will definitely assist in monitoring and evaluation of this substance at different formation and provide solution in prevent the migration of cadmium contaminant in soil and water environments.

Keywords: modeling and simulation, cadmium deposition and silty formation

1. Introduction

The rate arsenic in pore fluid on soil water environment has been thoroughly assessed, different types of pollution such as carcinogenic, mutagenic and teratogenic [plant et al, 2003] arsenic (As) is a major component in more than 245 minerals and is ubiquous in the surroundings [karl]. It is responsible for bladder, kidney, liver, lung, and skin cancers and is listed as a Class A human carcinogen by the USEPA [Mandal and Haris, 2002]. Both acute and chronic poisoning to humans has raised great concerns, especially in heavily contaminated areas such as Bangladesh and West Bengal, India and Nigeria. The severe health tribulations were described as ―the furthermost mass poisoning in human history‖ by World Health Organization [Chen and Haris, 2002 Eluozo and Nwaoburu, 2013]. The average concentration of arsenic in terrestrial environments is around 1.5 to 3 mg/kg. Arsenic in the environmental comes from natural and anthropogenic sources. Arsenic is present in dropping marine sediment, iron deposits, sedimentary iron ores and manganese nodules and is commonly associated with iron hydroxides and sulfides. Among the 245 minerals, approximately 60% are arsenates, 20% sulfides and sulfo-salts and the remaining 20% includes arsenides, arsenites, oxides, silicates and elemental arsenic [Vatamaan, et al,2000]. The levels of soil arsenic range from 0.1 to 40 mg/kg in various countries. Anthropogenic sources generally exceed natural sources by 3 to 1in the environment. Arsenic can substitute for Si, Al or Fe in silicates minerals; therefore, contaminated soils usually have arsenic-rich parent materials [Ritchie, 1980, Fittz and Wenzel 2002].The utilization of natural resources by human's releases arsenic into the air, water and soil. Arsenic may accumulate in soil through use of arsenical pesticides, application of fertilizers, dusts from burning of fossil fuels, and disposal of industrial and animal wastes. It has been estimated that there are 41% of the superfund sites in the USA are contaminated with arsenic [EPA, 1997], 1.4 million contaminated sites within the European Community impacted by arsenic [ETCS.1998], and more than 10,000 arsenic contaminated sites reported in Australia [9]. These anthropogenic sources will adversely affect plants, animals and microorganisms. The main arsenic producers were USA, Russia, France, Mexico, Germany, Peru, Namibia, Sweden, and China, and these countries accounted for about 90% of the world production [Smith and Alston, 2002 Eluozo and Nwaoburu,2013]. In the past, about 80% of arsenic consumption was for agriculture uses such as insecticides and pesticides. The inorganic arsenicals, primarily, sodium arsenite, were widely used since 1890 as weed killers, particularly as non-selective soil sterilants [Mandal and Suzuki, 2002]. Two thousand and five hundred tons of $H3AsO4$ were used as desiccants on 1,222,000 acres (about 495,000 ha) of U.S. cotton in 1964 [6]. Fluor - chromearsenic- phenol (FCAP), chromated copper arsenate (CCA) and ammoniacal copper arsenate (ACA) were used in 99% of the arsenical wood preservatives [10]. Several arsenic compounds are currently used for feed additives, such as $H3AsO4$, 3-nitro-4-hydroxy phenylarsonic acid, 4-nitrophenylarsonic acid etc Mebarg and ,Hartler, 2002 Karl, 2003]. Changes in arsenic speciation occurs both abiotically and biotically, the latter was catalyzed by organisms. Arsenite oxidation can be catalyzed by iron oxides, manganese oxides and organic compounds when the oxidation potential is high enough and usually at low pH (< 3), though it is slow. Most arsenite is oxidized microbiologically as a detoxification mechanisms or as elector donor, which are known as heterotrophic arsenite oxidizers (HAOs) or arsenic is somewhat unusual comparing with transition metals and metalloids. Plants growing on arsenate contaminated soils will assimilate high levels of arsenate unless they have altered phosphate transport mechanisms [Chen and stolz,2003]. In spite of that, arsenate resistance has been identified in a number of plant species growing on arsenic contaminated soils including *Andropogon scoparius, Agrostis castellana, A. delicatula, A. capillaries Deschampsia cespitosa,* and *Plantago lanceolata* [Sharpes et al, 2010]. In those plants, resistance is generally achieved via suppression of the high affinity phosphate uptake system. It is thought that this suppression reduces arsenate influx to a level at which the plant can detoxify by constitutive mechanisms [Mebarg and Macnair, 1994]. Thus, arsenate sensitivity is intimately linked to phosphate nutrition, with increased phosphate status leading to reduced arsenate uptake [Mebarg and Macnair, 1994]. Indeed, most arsenate resistant plants always suppress the high affinity uptake system and are insensitive to plant phosphorous status [Mebarg and Hertley, 2002, Anhini, 2009 Eluozo and Nwaoburu,2013].

2. Governing equation

$$V\frac{\partial q_2}{\partial t} = -V\frac{\partial q^2}{\partial x} \quad \text{..............} \quad (1)$$

We approach the system, by using the Bernoulli's method of separation of variables

$$q_2 = XT \quad \text{......................................} \quad (2)$$

i.e. $$V\frac{\partial q_2}{\partial t} = XT^1 \quad \text{...................................} \quad (3)$$

$$V\frac{\partial q_2}{\partial x} = X^1T \quad \text{......................................} \quad (4)$$

Put (2) and (3) into (2), so that we have

$$VXT^1 = -VX^1T \quad \text{......................................} \quad (5)$$

i.e. $$V\frac{T^1}{T} = V\frac{X^1}{X} = -\lambda^2 \quad \text{......................................} \quad (6)$$

Hence $$V\frac{T^1}{T} + \lambda^2 = 0 \quad \text{.............................} \quad (7)$$

i.e. $$X^1 + \frac{\lambda}{R}x = 0 \quad \text{...........................} \quad (8)$$

$$VX^1 + \lambda^2 X = 0 \quad \text{.............................} \quad (9)$$

From (8), $$X = ACos\frac{\lambda}{R}X + BSin\frac{\lambda}{\sqrt{R}}X \quad \text{.............................} \quad (10)$$

And (3) gives

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$$T = C\ell^{\frac{-\lambda^2}{V}t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

And (3) gives

If T = $\dfrac{d}{v}$ and $x = v = v..t$ we have

$$C_2 = \left(A\,Cos\frac{\lambda}{V}\frac{d}{v} + B\,Sin\frac{\lambda}{\sqrt{V}}\frac{d}{v} \right) C\ell^{\frac{-\lambda^2}{V}V.T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

Subject to equation (12) to conditions, so that we have

$$q_o = AC \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

Equation (13) becomes

$$q_2 = q_o \ell^{\frac{-\lambda^2}{V}x} \; Cos\frac{\lambda}{\sqrt{V}}t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

Again, at

$$\left.\frac{\partial q_2}{\partial t}\right|_{t = 0,\ B} = 0,\ x = 0$$

Equation (14) becomes

$$\frac{\partial q_2}{\partial t} = \frac{\lambda}{\sqrt{V}} q_o \ell^{\frac{-\lambda}{V}x} \; Sin\frac{\lambda}{\sqrt{V}}t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

i.e. $0 = -\dfrac{qo\lambda}{\sqrt{V}}\; Sin\dfrac{\lambda}{V}0$

$Co\dfrac{\lambda}{V} \neq 0$ Considering NKP

Which is the substrate utilization for microbial growth (population) so that

$$0 = qo\frac{\lambda}{\sqrt{V}} \; Sin\frac{\lambda}{\sqrt{V}}B \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

$$\Rightarrow \frac{\lambda}{R} = \frac{n\pi}{2} n,1,2,3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

$$\Rightarrow \lambda = \frac{\lambda}{V} = \frac{n\pi\sqrt{R}}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

So that equation (14) becomes

$$\Rightarrow q_2 = qo\,\ell^{\frac{-n^2\pi^2 v}{2}t} \, Cos\frac{n\pi\sqrt{V}}{2\sqrt{V}}x \qquad \text{..............................} \qquad (19)$$

If T = $\frac{d}{v}$ and X = $v.t$ we have

$$\Rightarrow q_2 = qo\,\ell^{\frac{-n^2\pi^2 V}{2}\frac{d}{v}} \, Cos\frac{n\pi}{2}v.t \qquad \text{..............................} \qquad (20)$$

3. Materials and method

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

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 cadmium at Different Depth

Depths [M]	Concentration[Mg/L]
3	0.021
6	0.082
9	0.19
12	0.32
15	0.51
18	0.74
21	1.23
24	1.32
27	1.62
30	2.06

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Table2: Concentration of cadmium at Different Time

Time [Per Day]	Concentration[Mg/L]
10	0.021
20	0.082
30	0.19
40	0.32
50	0.51
60	0.74
70	1.23
80	1.32
90	1.62
100	2.06

Table 3: Comparison of Theoretical and Experimental Values of cadmium concentration at Different depths

Depths [M]	Theoretical values [Mg/l]	Experimental values [Mg/L]
3	0.021	0.024
6	0.082	0.092
9	0.19	0.21
12	0.32	0.36
15	0.51	0.61
18	0.74	0.84
21	1.23	1.27
24	1.32	1.39
27	1.62	1.73
30	2.06	2.11

Table 4: Comparison of Theoretical and Experimental Values of cadmium concentration at Different Time

Time [Per Day]	Theoretical values [Mg/l]	Experimental values [Mg/L]
10	0.021	0.024
20	0.082	0.092
30	0.19	0.21
40	0.32	0.36

50	0.51	0.61
60	0.74	0.84
70	1.23	1.27
80	1.32	1.39
90	1.62	1.73
100	2.06	2.11

Table 5: Concentration of cadmium at Different Depths

Depths [M]	Concentration[Mg/L]
3	1.10E-05
6	4.60E-06
9	1.02E-05
12	1.81E-05
15	2.83E-05
18	4.08E-05
21	5.56E-05
24	7.27E-05
27	9.20E-05
30	1.13E-04

Table 6: Concentration of cadmium at Different Time

Time [Per Day]	Concentration[Mg/L]
10	1.10E-05
20	4.60E-06
30	1.02E-05
40	1.81E-05
50	2.83E-05
60	4.08E-05
70	5.56E-05
80	7.27E-05
90	9.20E-05
100	1.13E-04

Table 7: Comparison of Theoretical and Experimental Values of cadmium concentration at Different Time

Depths [M]	Theoretical values [Mg/l]	Experimental values [Mg/L]
3	1.10E-05	1.15E-05

6	4.60E-06	4.80E-06
9	1.02E-05	1.23E-05
12	1.81E-05	1.91E-05
15	2.83E-05	2.93E-05
18	4.08E-05	4.23E-05
21	5.56E-05	5.66E-05
24	7.27E-05	7.57E-05
27	9.20E-05	9.55E-05
30	1.13E-04	1.23E-04

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

Time [Per Day]	Theoretical values [Mg/l]	Experimental values [Mg/L]
10	1.10E-05	1.15E-05
20	4.60E-06	4.80E-06
30	1.02E-05	1.23E-05
40	1.81E-05	1.91E-05
50	2.83E-05	2.93E-05
60	4.08E-05	4.23E-05
70	5.56E-05	5.66E-05
80	7.27E-05	7.57E-05
90	9.20E-05	9.55E-05
100	1.13E-04	1.23E-04

Table 9: Concentration of cadmium at Different Time

Depths [M]	Concentration[Mg/L]
3	2.00E-01
6	4.10E-01
9	6.20E-01
12	8.30E-01
15	1.04E+00
18	1.25E+00
21	1.46E+00
24	1.67E+00
27	1.88E+00
30	2.09E+00

Table 10: Concentration of cadmium at Different Time

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Time [Per Day]	Concentration[Mg/L]
10	2.00E-01
20	4.10E-01
30	6.20E-01
40	8.30E-01
50	1.04E+00
60	1.25E+00
70	1.46E+00
80	1.67E+00
90	1.88E+00
100	2.09E+00

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

Depths [M]	Theoretical values [Mg/l]	Experimental values [Mg/L]
3	2.00E-01	0.22
6	4.10E-01	0.39
9	6.20E-01	0.59
12	8.30E-01	0.86
15	1.04E+00	1.12
18	1.25E+00	1.29
21	1.46E+00	1.51
24	1.67E+00	1.71
27	1.88E+00	1.98
30	2.09E+00	2.14

Table 12: Concentration of cadmium at Different Time

Depths [M]	Concentration[Mg/L]
3	4.00E-02
6	8.00E-02
9	1.20E-01
12	1.60E-01
15	2.00E-01
18	2.40E-01
21	2.80E-01
24	3.20E-01
27	3.60E-01
30	4.00E-01

Table 13: Concentration of cadmium at Different Time

Time [Per Day]	Concentration[Mg/L]
10	4.00E-02
20	8.00E-02
30	1.20E-01
40	1.60E-01
50	2.00E-01
60	2.40E-01
70	2.80E-01
80	3.20E-01
90	3.60E-01
100	4.00E-01

Table 14: Comparison of Theoretical and Experimental Values of cadmium concentration at Different Depths

Depths [M]	Theoretical values [Mg/l]	Experimental values [Mg/L]
3	4.00E-02	0.045
6	8.00E-02	0.085
9	1.20E-01	0.14
12	1.60E-01	0.18
15	2.00E-01	0.22
18	2.40E-01	0.26
21	2.80E-01	0.31
24	3.20E-01	0.36
27	3.60E-01	0.4
30	4.00E-01	0.44

Table 15: Comparison of Theoretical and Experimental Values of cadmium concentration at Different Time

Time [Per Day]	Theoretical values [Mg/l]	Experimental values [Mg/L]
10	4.00E-02	0.045
20	8.00E-02	0.085
30	1.20E-01	0.14
40	1.60E-01	0.18
50	2.00E-01	0.22
60	2.40E-01	0.26
70	2.80E-01	0.31

80	**3.20E-01**	**0.36**
90	**3.60E-01**	**0.4**
100	**4.00E-01**	**0.44**

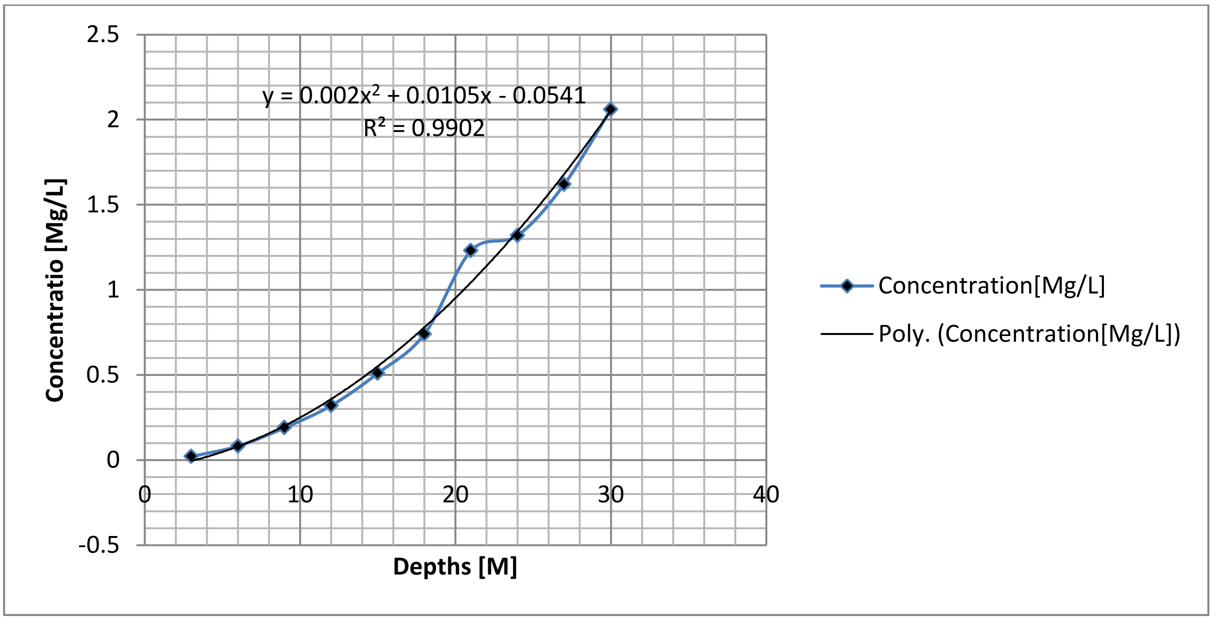

Figure 1: Concentration of cadmium at Different Depths

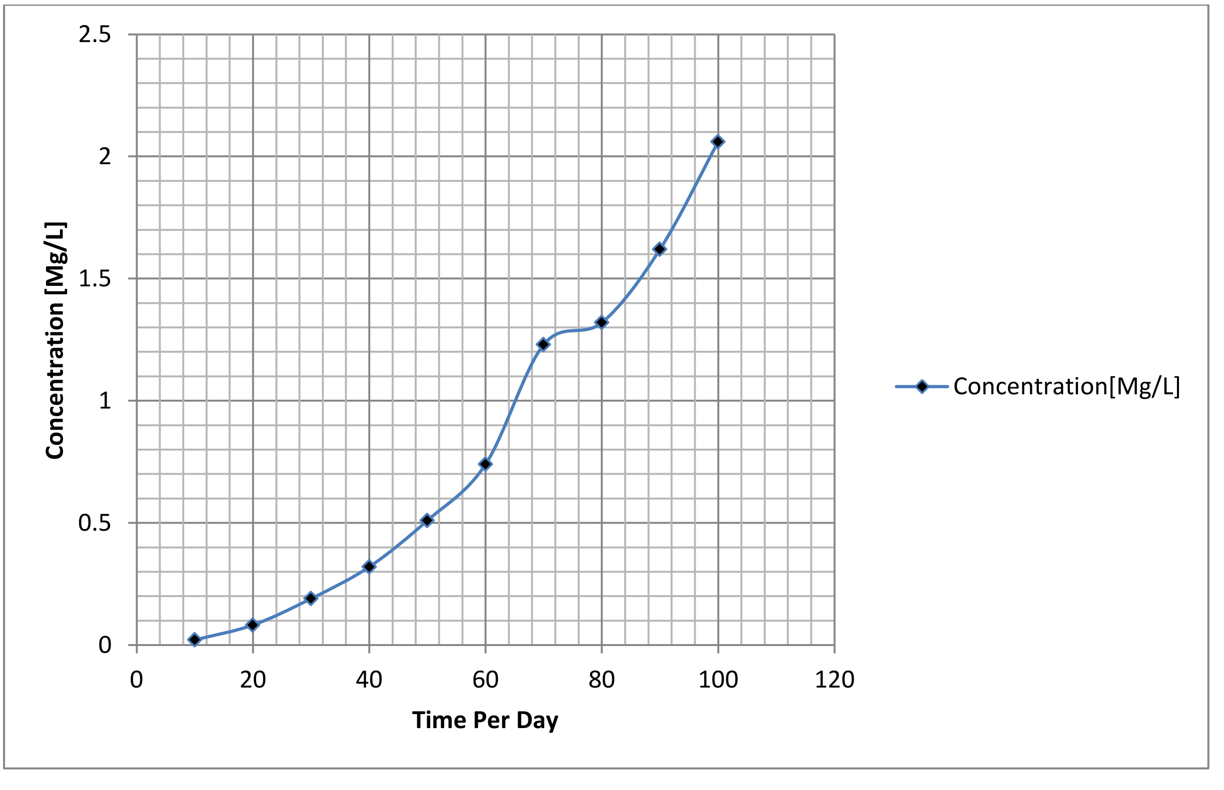

Figure 2: Concentration of cadmium at Different Time

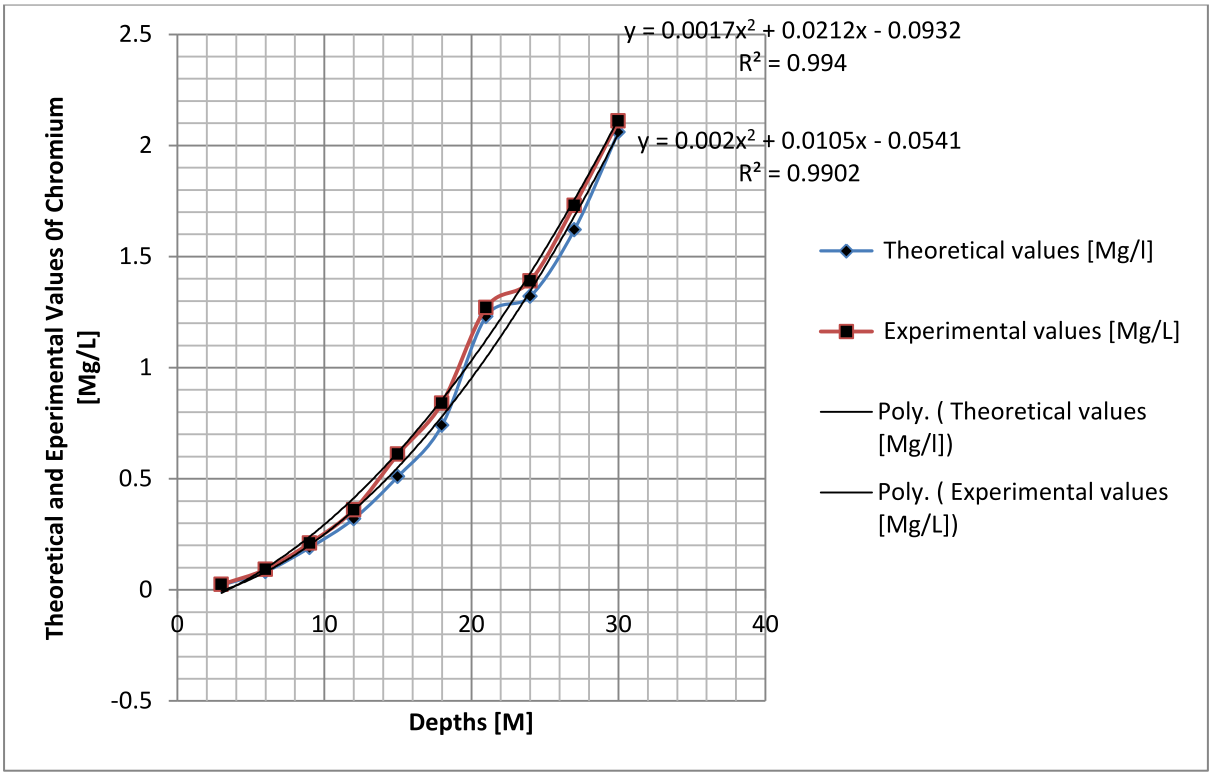

Figure 3: Comparison of Theoretical and Experimental Values of cadmium concentration at Different Depths

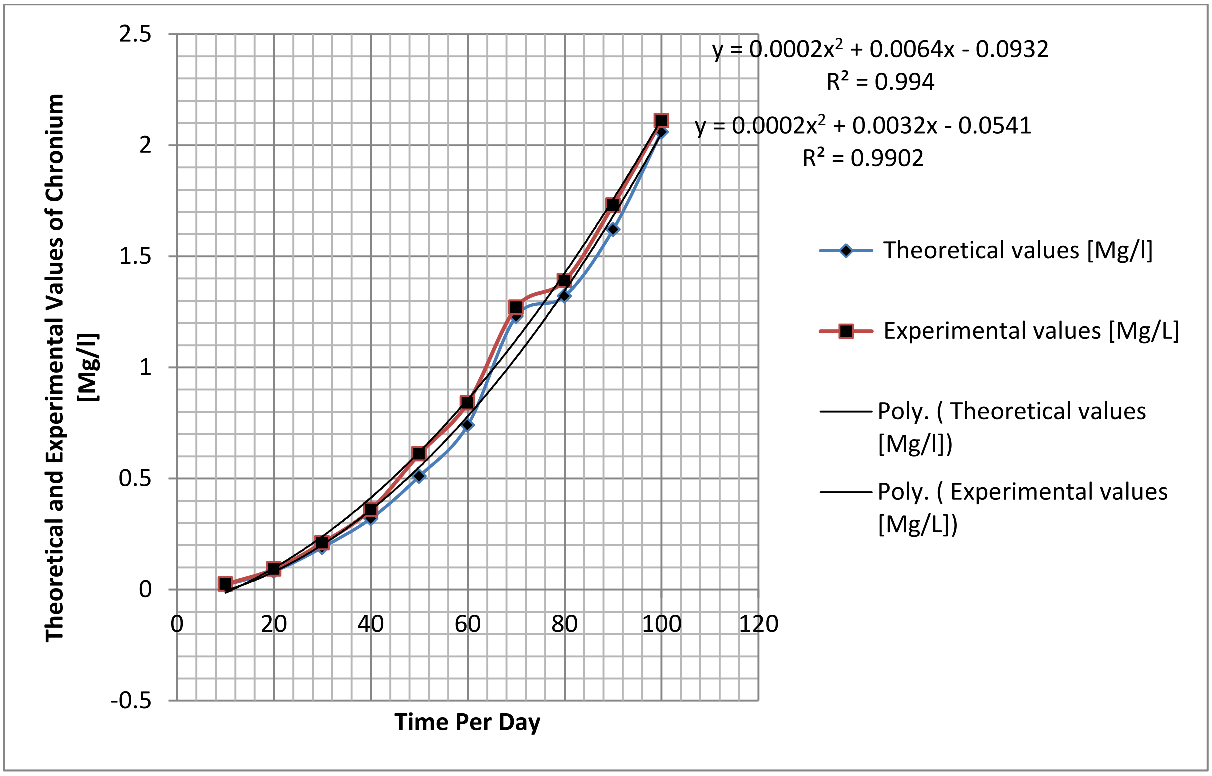

Figure 4: Comparison of Theoretical and Experimental Values of cadmium concentration at Different Time

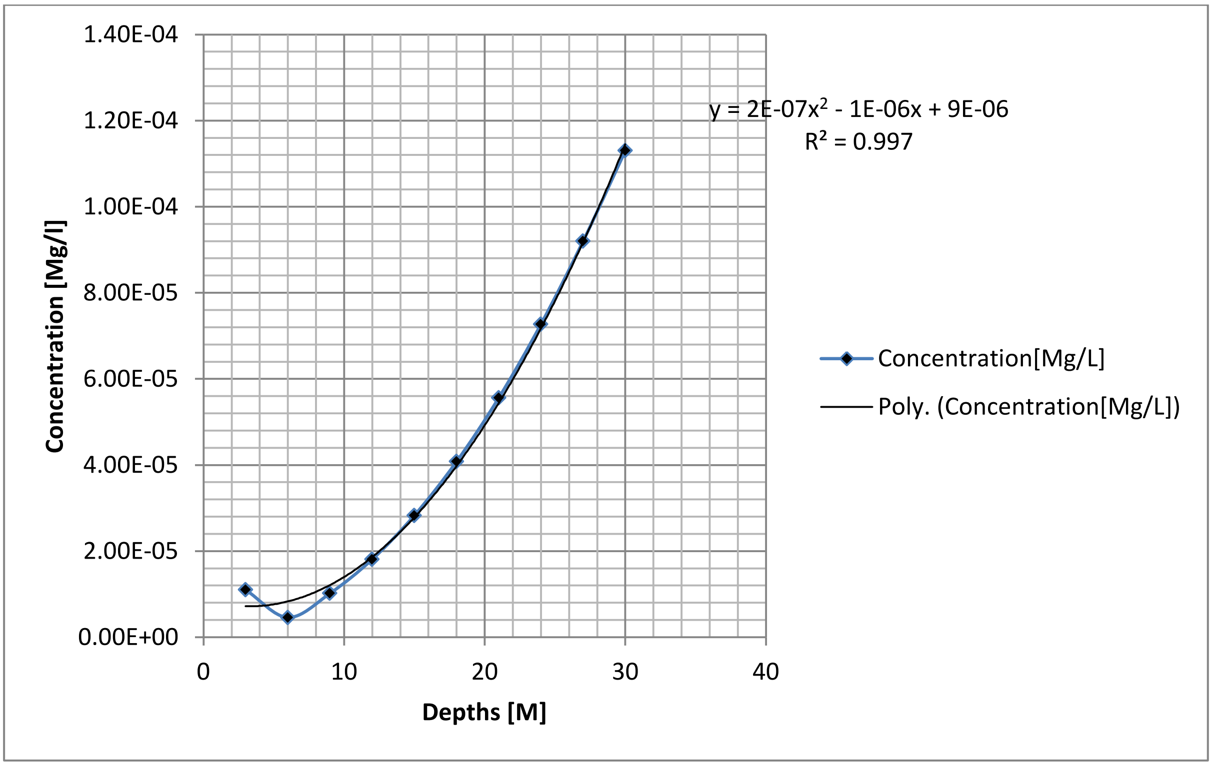

Figure 5: Concentration of cadmium at Different Depths

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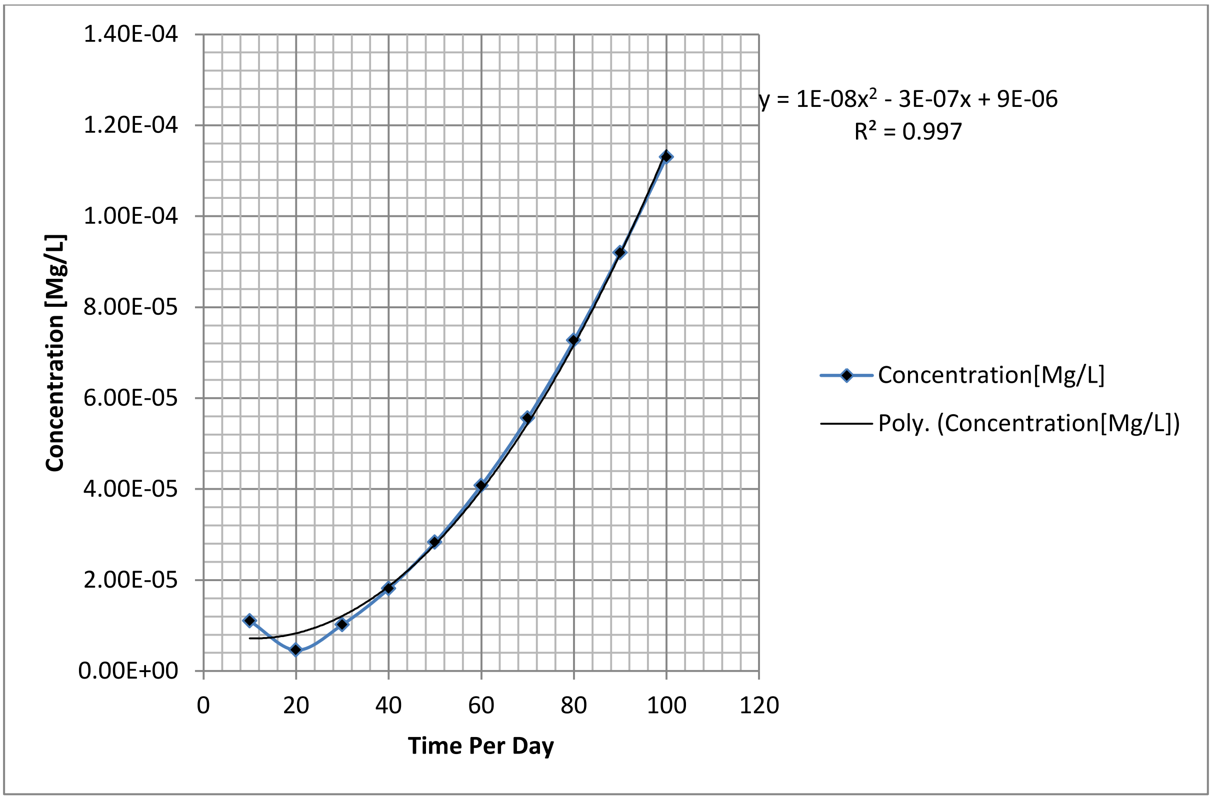

Figure 6: Concentration of cadmium at Different Time

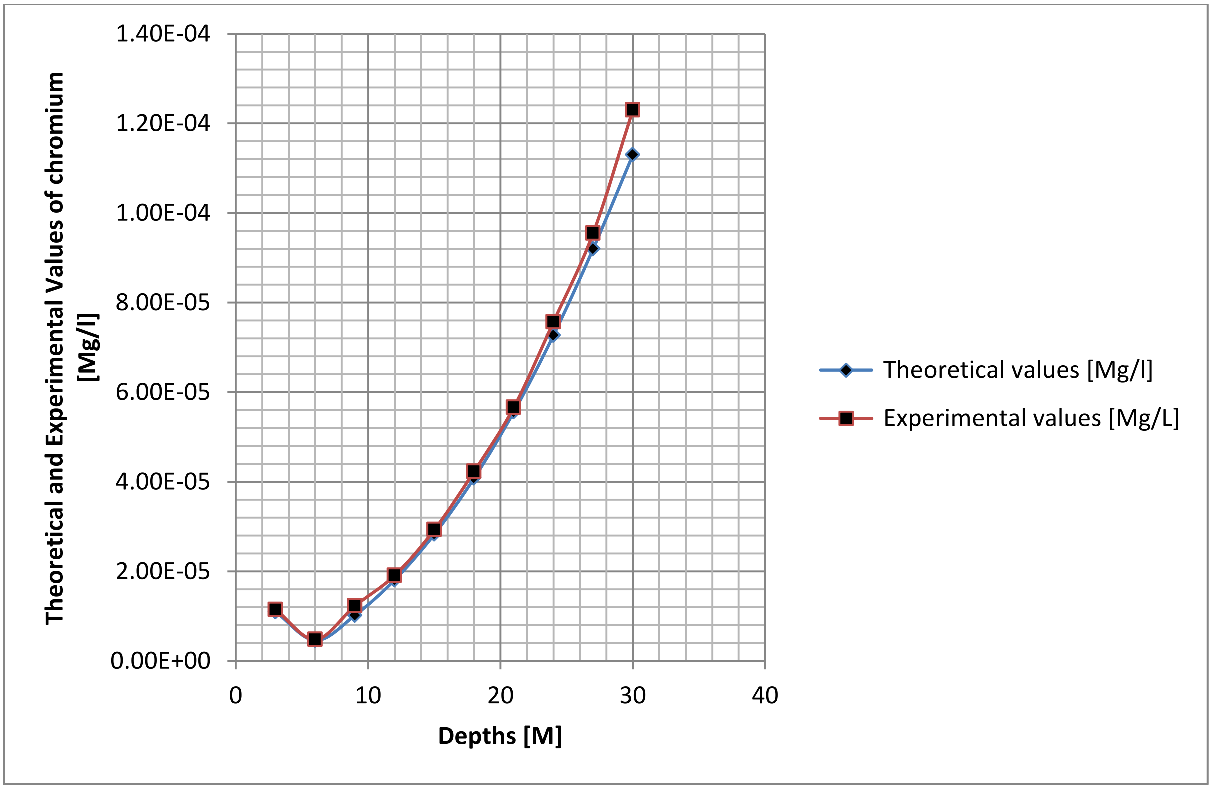

Figure 7: Comparison of Theoretical and Experimental Values of cadmium concentration at Different Depths

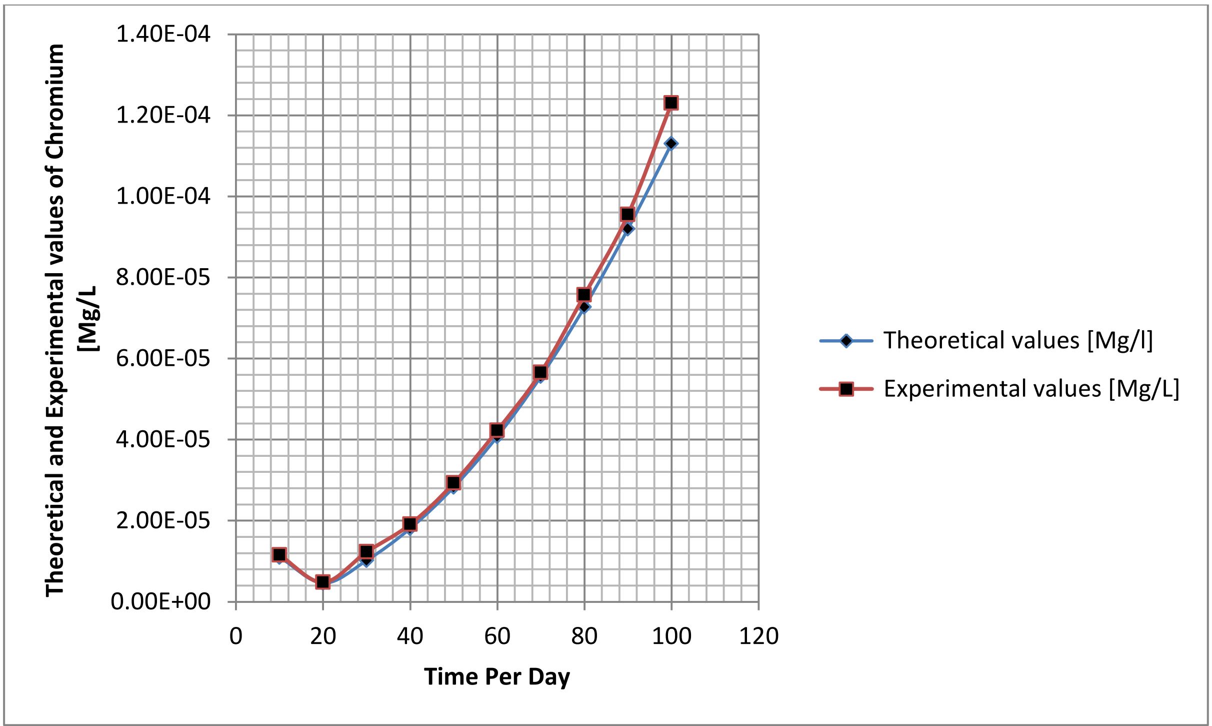

Figure 8: Comparison of Theoretical and Experimental Values of cadmium concentration at Different Time

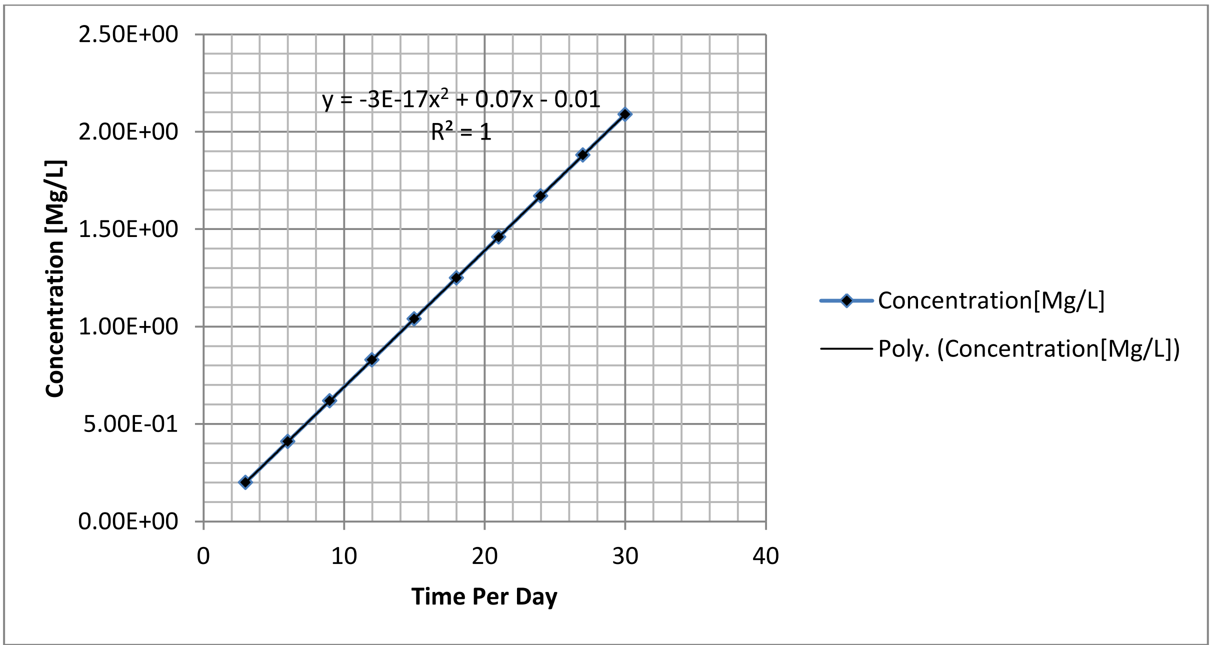

Figure 9: Concentration of cadmium at Different Time

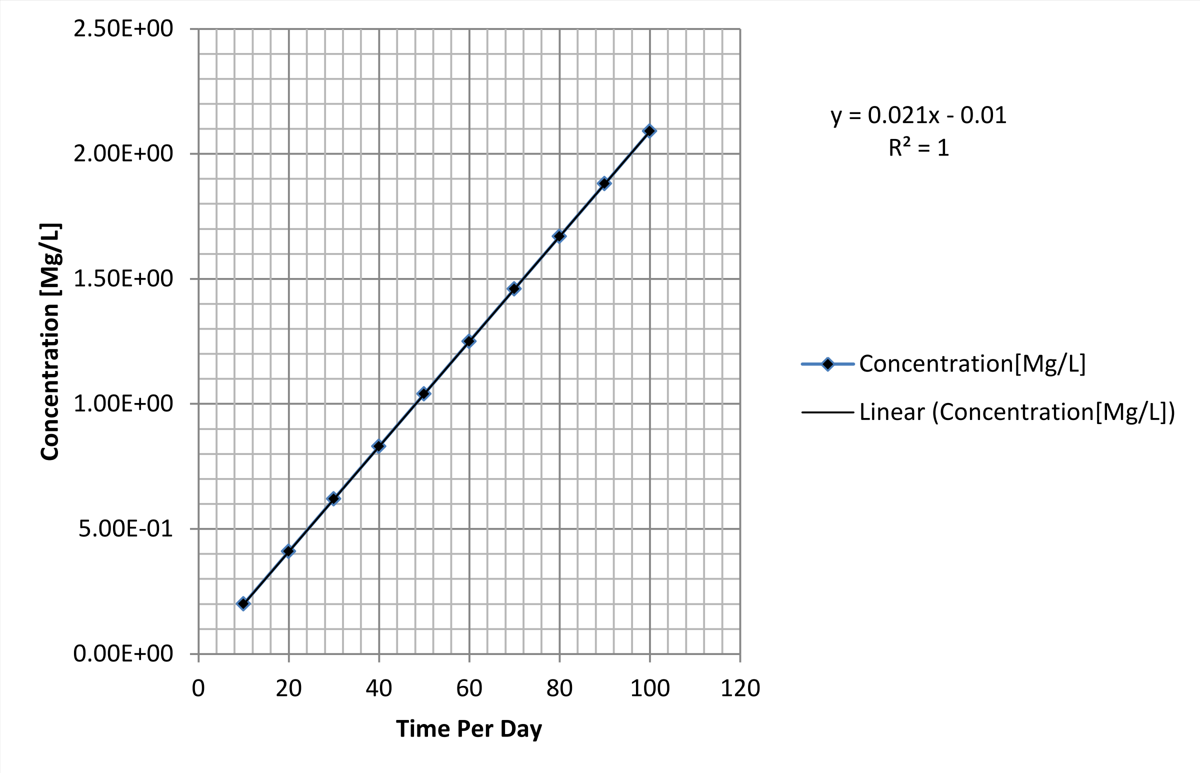

Figure 10: Concentration of cadmium at Different Time

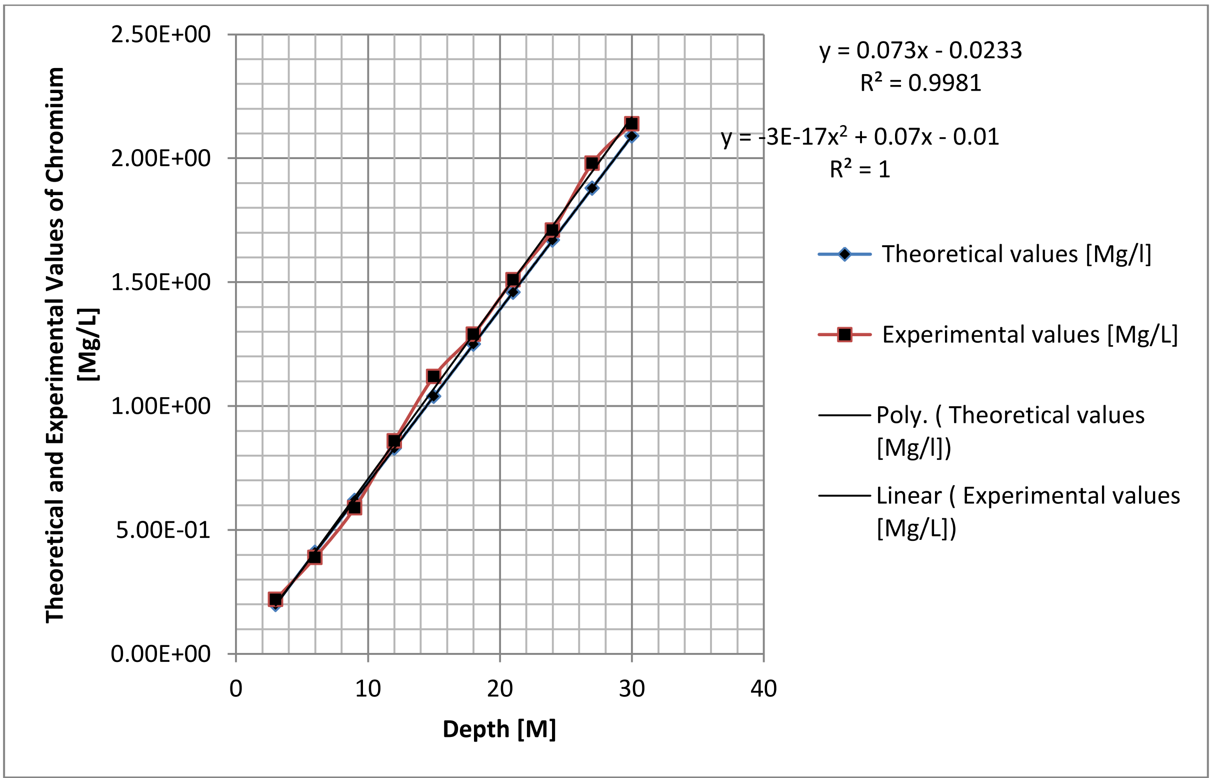

Figure 11: Comparison of Theoretical and Experimental Values of cadmium concentration at Different Depths

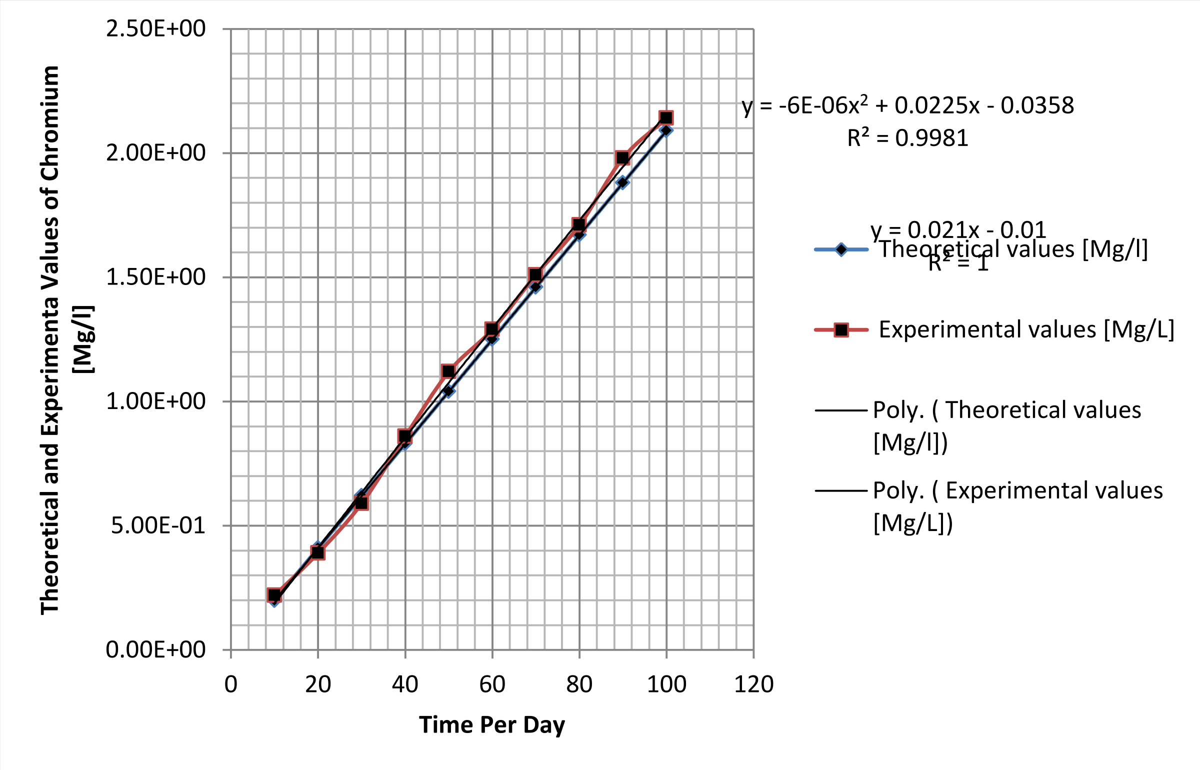

Figure 12: Comparison of Theoretical and Experimental Values of cadmium concentration at Different Time

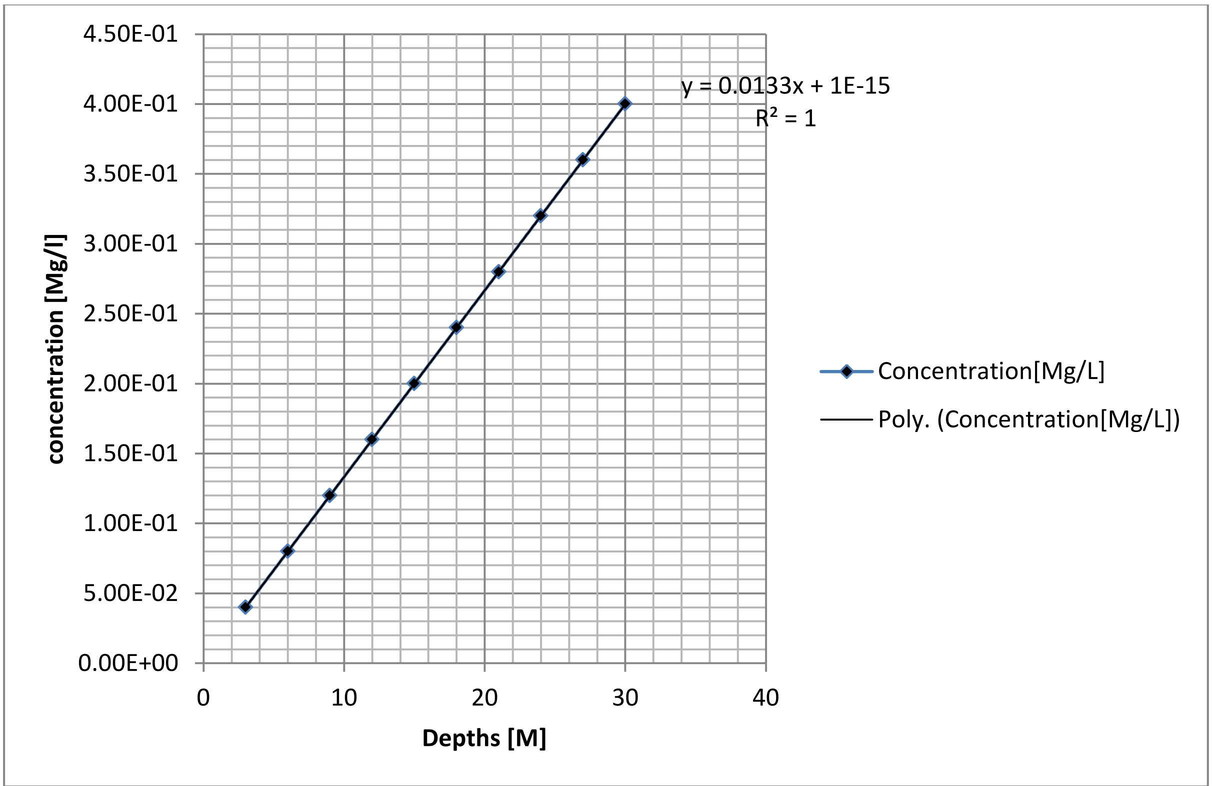

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Figure 13: Concentration of cadmium at Different Depths

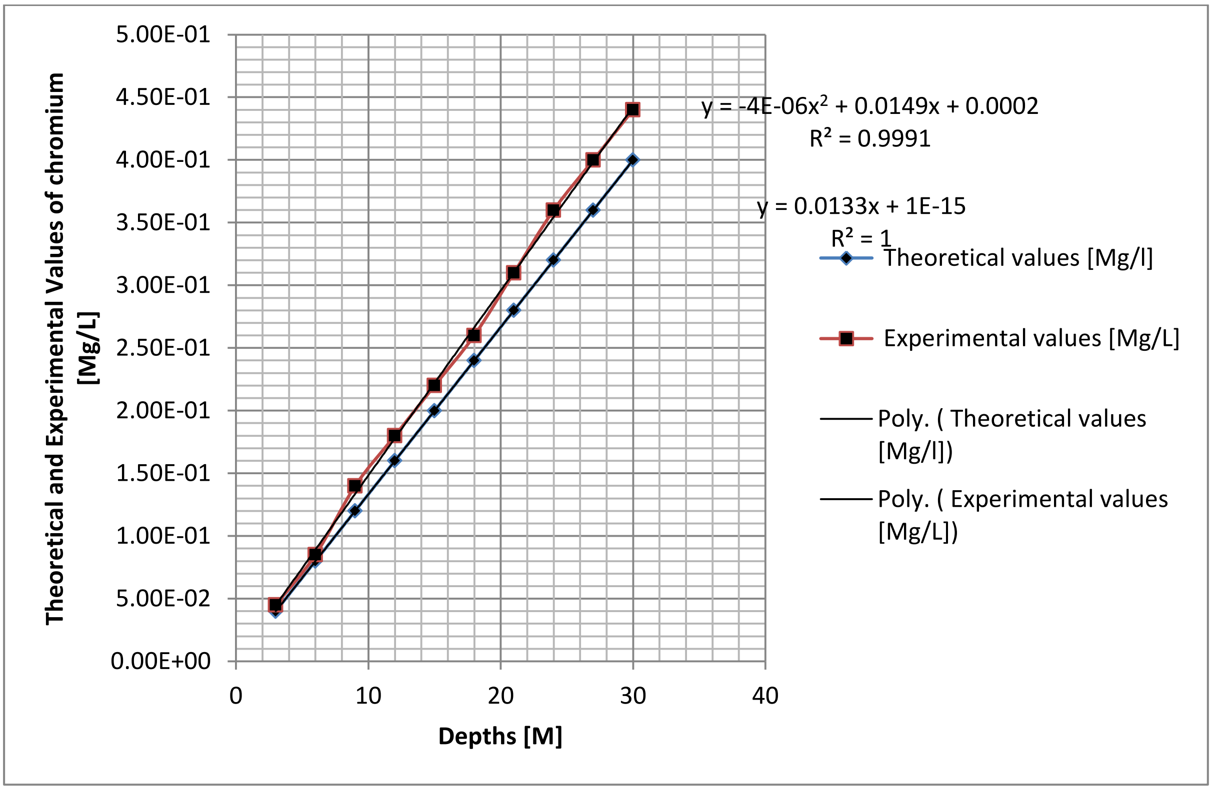

Figure 14: Comparison of Theoretical and Experimental Values of cadmium concentration at Different Depths

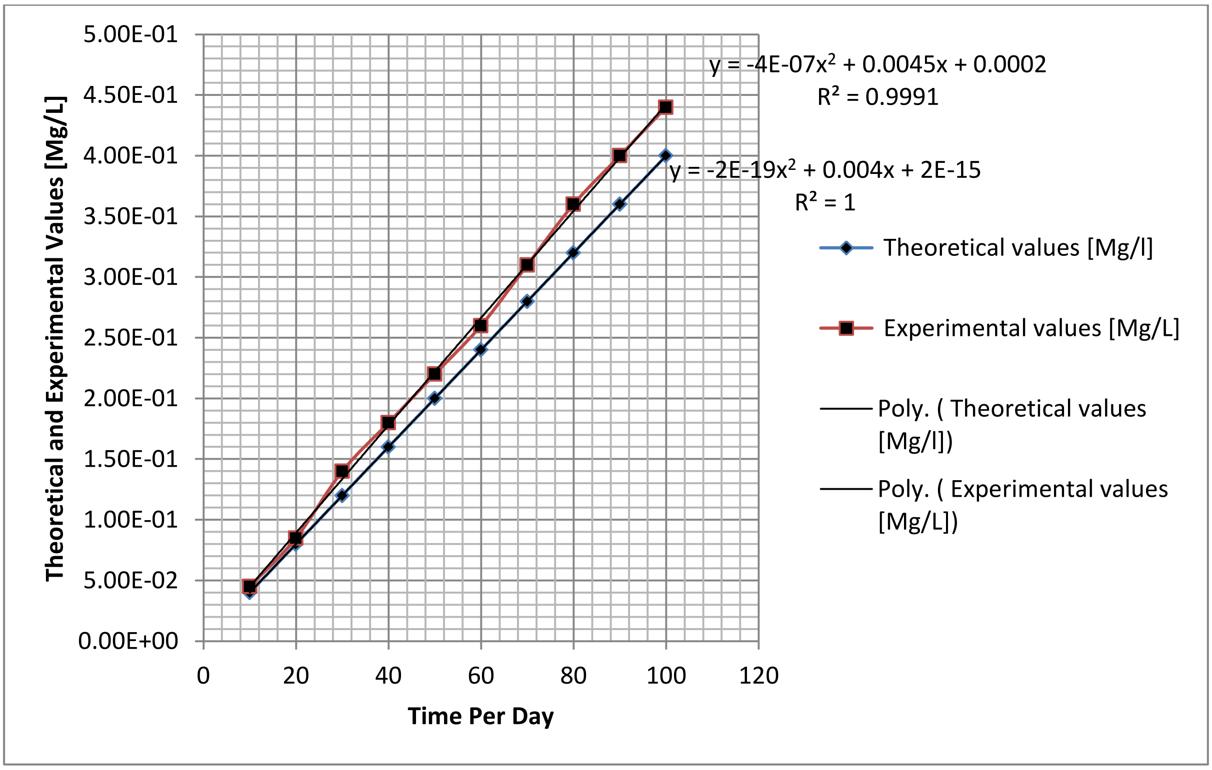

Figure 15: Comparison of Theoretical and Experimental Values of cadmium concentration at Different Time

The presented figures has express it deposition of the substances in progressive phase condition, the rate of transport at progressive direction were base of the deposition of void ratio predominantly with highest degree of formation characteristics in the study environment. Such development influences the transport system of cadmium in the study area, the deposition of this substances has developed lots of poisonous ill health for the settlements, different concentration results are found from the simulated results, the rate of void ratio variation were examined to actually monitor or evaluated the best option in the prevention and management of soil pollution in the study environment, the study defined the objective of eradicating this substance from soil and water, in line with this conceptual frame work, the results from the express figures has establish a baseline on the migration strength of the substances, this was pressured through the stratification influences in the study area, the exponential condition found in cadmium deposition were base on the pressured from the predominant void ratio that has been found to play major roles inn the transport system of cadmium in the study area. The figures present condition has also see the rates of microelements not able to inhibit the deposition of cadmium; the deposition level in the formation could not allow inhibition. Simulations of the model express the behaviour in this direction, because it has express homogeneous stratification of the formation to a large extend. The influences from deposited void ratio are base on geological setting of the study environment, such deltaic nature should be noted also due to frequency of high rain intensities and climatic change, because it will definitely pressures the migration process of the substances within a short period of time.

4. Conclusion

The rate of cadmium in soil formation has developed lots of concern, this is base on the level of ill health it has cause in the study environments, the situation of cadmium deposition in the formation has cause lots of pollution due to the rate of hazard impact in soil and water environments, the study has provide a platform for thorough assessment of this contaminant in cadmium deposition and migration of predominant homogeneous stratum it deposit, the developed model from formulated system generated model that were simulated to monitor and evaluate the deposition of cadmium in the formations. The results from the developed model values presented in figures shows the behaviour of cadmium deposition in soil and water environment, rapid and sluggish migration were observed in different formation and location, the rate of concentration varies reflecting on the different observed percentage of void ratio that influenced the deposition and migration of the substance in the study environment. The developed model for the study is imperative because the simulated results has provided platform for practicing experts to monitor and assess the deposition and rate of cadmium in soil and water environments.

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