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RESEARCH ARTICLE OPEN ACCESS

Modeling the Retention of Diesel Oil Spill in Bori-Ogoni Soil

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ABSTRACT
Retained diesel spill in soil causes problems which include, contamination of soils, bioaccumulation of hydrocarbon in humans resulting to carcinogenesis and mutagenesis, destruction and extinction of some plants and animals. This research is aimed at modeling the retention of diesel fuel spill in Niger Delta soil. The objectives are to monitor the retention of diesel at given soil depths; different contaminant volumes and rainfall intensities, develop a model that will describe the retention of diesel in unsaturated soil zone at different spill scenarios. The method used in generating the experimental design was response surface method, which uses two (2) independent variables that includes contaminant volume, rainfall intensity and a constant variable known as the soil depth. XLSAT software was used to develop the model for retained Total Petroleum Hydrocarbon (TPH) after diesel spill on ground surface. The contaminant volume, rainfall intensity and soil depth used are, 50ml, 225ml, 400ml ;5mm/hr, 7.5mm/hr, 10mm/hr and constant depth of 1000mm respectively. The soil was artificially contaminated with different contaminant volumes of 50ml, 225ml and 400ml of diesel. Varying rainfall intensity of 5mm/hr, 7.5mm/hr and 10mm/hr were simulated on the soil. Soil test such as sieve analysis, liquid and plastic limit, organic mass content, permeability and moisture content were conducted on the soil. The results obtained classified the soil as a well graded A-7-5 silty clay soil with permeability coefficient and organic mass content of 4.32E-03m/s and 15.13% respectively. Conclusively, the concentrations of TPH retained in the soil decreased with increased rainfall intensity and increases with increased contaminant volume. Increased rainfall intensity on diesel spilled land will impact more on ground water while increased contaminant volume will impact more on diesel spilled land and ground water depending on soil properties and structure. Zero tolerance to diesel spill will prevent impacting on the groundwater quality. Correlation coefficient of 0.95 of the developed validated retention model implies that it can adequately predict the retention of diesel in unsaturated soil zone following release. Ministry of environment in alliance with the Niger Delta Development Commission, NOSDRA and other sister agencies should sponsor the adoption and implementation of the developed model in diesel oil spill reclamation works in Niger delta soil.

KEYWORD: Retention Model, Diesel fuel, Niger Delta soil, Gas Chromatography, Organic Content, Retained Concentration, Creative Innovations and Rainfall Intensity.

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I. INTRODUCTION

Water-oil fluid interaction in soil possess some constrain which includes soil and ground water contamination (Ericson, 2017) and (Amie-Ogan, Petaba, Leyira, Nwikina, Philip-Kpae, and Akpan, 2022), destruction of animals and plants (Richard , John, Sarah, Lawrence, Jackson, Matthew, Julianne, Sandro and Dale, 2017), acute and chronic infection of humans living in the contaminated zones (Ruben , Oksana , Chen., Einav ,Tirza and Yosef ,2018), destruction of aquatic lives (Zock, 2017), destruction of the ecosystem. (Bautista, and Rahman, 2016), extinction of plants and animals (Laffon, Pásaro and Valdiglesias,2016). Oil spillages deteriorate soil properties and impair plant growth (Fowzia and ANM2018). The work of Obire and Nwaubeta (2018) described the effects of refined petroleum hydrocarbon on the physiochemical and bacteriological characteristics of soil. Brakorenko and Korotchenko, (2016), Richard , John, Sarah, Lawrence, Jackson, Matthew, Julianne, Sandro and Dale, (2017),

Aniefiok, Thomas, Clement, Ekpedeme and Iniemem (2018), Mohammadi, Dehestani, Aff, Shooshpasha and Asadollahi, (2015) discussed on the impact of petroleum products on soil. The work of Sharma ., Muskan , Ojha . and Shukla , (2018) investigated on the effect of contaminant transport in soils.

Diesel spills in Bori are mainly caused by accidents, ruptured of pipelines and spillages caused by loss of containment (UNEP report, 2011) and (Petaba, Badom, Pepple, Amie-Ogan, Nwikina, and Akpan, 2022). Diesel is the major petroleum products used in the area by the polytechnic, banks, hotels, restaurants and eateries due to lack of power in the area (Otu and Oloidi,2018; Oluwaniyi ,2018). Hence, it is used as petroleum product for this research.

This study is aimed at developing a retention model of water-oil fluid interaction in the Niger Delta soil with specific objectives of monitoring the retention of diesel at given soil depths, monitoring the retention of diesel in unsaturated soil zone following the release of different volumes of diesel, assess the impact of various rainfall intensities on the retention of diesel, develop a model that will describe the retention of diesel in the unsaturated soil zone at different release scenarios (Ugwoha, Nwankwo, and Okoronkwo,2016) and (Amie-Ogan et al., 2022).

Whenever there is a spill, some spilled products infiltrate to the ground water and contaminate it as in the case of Ogali in Eleme in Ogoni, while some proportions of it remain in the soil and cause damages to plants and animals (UNEP report, 2011) and (Gbinu, Mahmud, Akpan, Badom, Nwiyor, and Letam, 2022). In this research, oil spill locations in Bori metropolis was identified; soil samples was obtained from the areas and tested in laboratory to classify it. Sieve analysis, liquid limits, plastic limits, plasticity index, organic content and moisture content test was done to classify the soil. Permeability and infiltration test was also be done to determine the K/D factor of the soil (Yang, Yang, Duand Lei,2018).

Three basic apparatuses were fabricated to help simulate rainfall at varying intensities, contaminate the soil at varying contaminant volume and obtain the leached concentration. The apparatuses fabricated are auger rig undisturbed soil collector, lysometer with a mesocosm and a rainfall simulator. Surface response method was used to obtain the experimental design for the number of runs and samples to be tested. After the simulations, gas chromatography was used to test for TPH present in the retained concentration of the samples. Surface response method and excel stats was used to develop the model for retained concentration (Amie-Ogan et al., 2022).

Extraction of TPH from soil. The soil samples were firstly dried to remove the moisture content, weighed and measured. 5g of soil was measured using the analytical weighing balance.50ml of extraction solvent (Hexane) was added into well washed and dried bottle. It was agitated for 30mins before separating using the filter papers. The process of filtration was done quickly to avoid escape of the solution, the soil particles were thrown away while the remaining samples (solvent) were well arranged and labeled in a tube for identification as shown in Plate 1 (Petaba et al., 2022).

II. MATERIALS AND METHODS

The materials used for this research include, rain fall simulator, lysometer with a mesocosm., diesel, auger rig undisturbed soil collector, soil samples and RSM Excel Stat. Program. The method deployed in this research is base on the work of Amie-Ogan et al. (2022).

2.1 MODEL ASSUMPTIONS

The following assumptions were considered in development of the model.

i. The soil is a silty clay soil common in Bori-Ogoni land.
ii. The rain fall intensity is simulated to vary between 5mm/hr, 7.5mm/hr and 10mm/hr.
iii. The soil depth is 1000mm.
iv. The diesel contaminant volume vary from 50ml, 225ml and 400ml.

III. RESULTS AND DISCUSSIONS

The results are presented and discussed below.

3.1 SOIL SAMPLE CONCENTRATION RETAINED CONCENTRATIONS OF TOTAL PETROLEUM HYDROCARBONS (TPHS)

Generally, the concentrations of TPH retained increases with increased volume of contaminant and decreases with increased rainfall intensity as shown in table 1

Table 1. Retained concentrations of TPH for various rainfall intensities and contamination volumes

Observation	Sort order	Run order	Repetition	Contam. vol	Rainfall intensity	Retained
Obs1	1	1	1	50	5	21.13
Obs2	2	2	1	225	5	27.63
Obs3	3	3	1	400	5	30.56
Obs4	4	4	1	50	7.5	15.1
Obs5	5	5	1	225	7.5	21.98
Obs6	6	6	1	400	7.5	556.17
Obs7	7	7	1	50	10	24.9
Obs8	8	8	1	225	10	21.24
Obs9	9	9	1	400	10	27.89

Discussion of the result in table 1

i. Generally, the concentrations of TPH retained increases with increased contaminant volume and decreases with increased rainfall intensity as shown in Table 1 (Akpan, Bob, Badom, Pepple, Nwiyor, and Ndam, 2022).
ii. This implies that more diesel will be retained in the soil with increase diesel spill and less diesel will be retained with increased rainfall intensity due to the soil k/d factor (Yang, Yang, Du and Lei, 2018).

3.2 RETAINED CONCENTRATIONS OF DIESEL

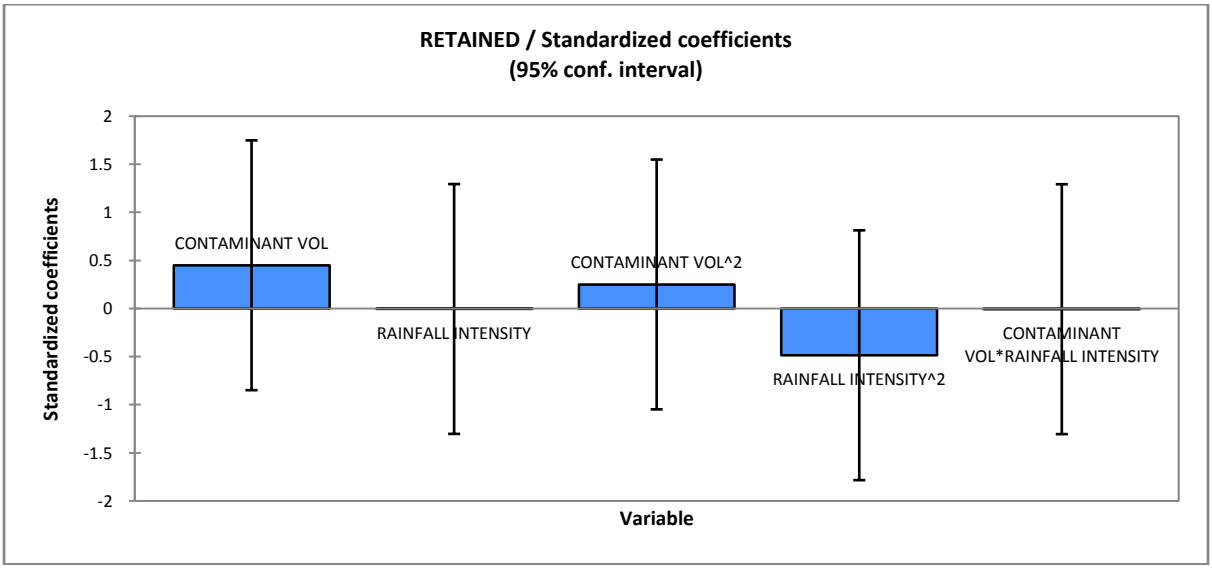

Figure 1.Wash out / Standardized coefficients

Discussion of the result in figure 1

i. The standardized coefficient of the contaminant volume, contaminant vol^2 and rainfall intensity^2 of 0.5, 0.25 and -0.5 respectively should be taken more seriously in terms of retained concentration of diesel spill because they are higher compared to rainfall intensity and contaminant vol * rainfall intensity as shown in Figure 1.
ii. Based on figure 1, since the standardized coefficient of the contaminant volume is the highest at 0.25 in implies that increase contaminant volume of spilled diesel will result in increase quantity of retained diesel concentration in the soil.
iii. Based on figure 1, the rainfall intensity is approximately zero; this implies that increased rainfall intensity will result in decreased amount of retained concentration. Hence rainfall intensity can be used to reclaim contaminated soil (Akpan et al., 2022).

3.3 RELATIONSHIP BETWEEN RETAINED CONCENTRATIONS AND INDEPENDENT VARIABLES

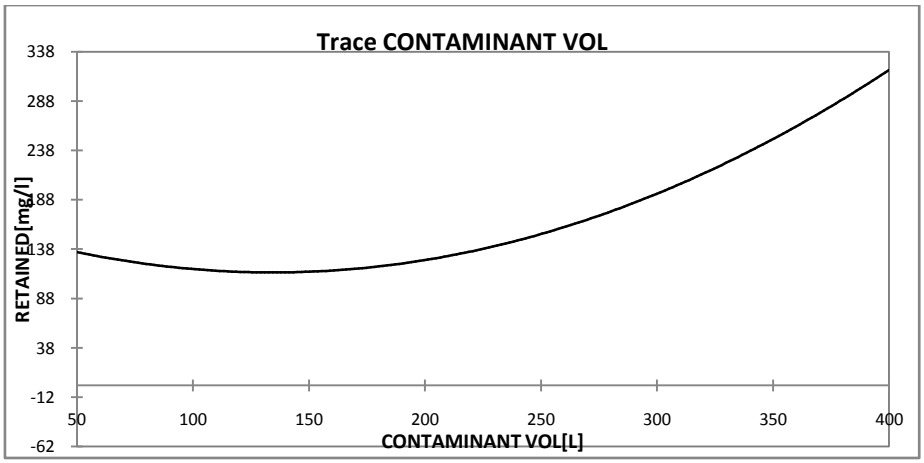

Figure 2. Retention Concentration through varying diesel traces contaminant volumes

Discussion of the result in figure 2

i. Figure 2 showed that an increase in contaminant volume from 110ml to 400ml results in a simultaneous increase in the retained concentration from 100mg/l to 800mg/l.

ii. It means that an increase in contaminant volume will impact more on groundwater contamination than change rainfall intensity (Obire and Nwaubeta, 2018).

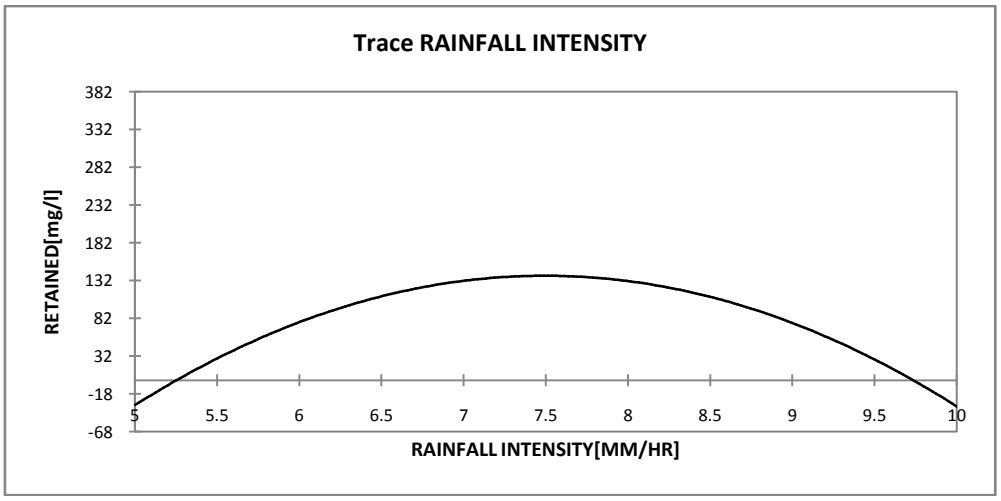

Figure 3. Retention Concentration through varying diesel traces rainfall intensities (mm/hr)

Discussion of the result in figure 3

i. Figure 3 showed that increase in rainfall intensity will initially cause an increase in retained diesel concentration, however at the passage of time further increase in rainfall intensity will result to a simultaneous decrease in the retained diesel concentration.

ii. This implies that the concentrations of TPH retained decreases with increased rainfall intensity (Jian, Omar, Saeed, and Sokrates, 2018).

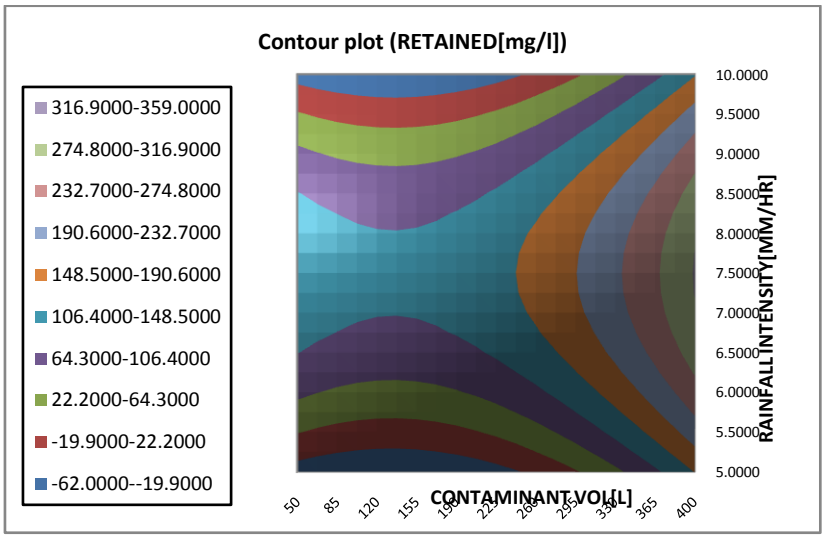

Figure 4. Contour plot (Retained [mg/l])

Discussion of the result in figure 4.

i. The 2D contour map of figure 4. showed the top view of the developed model.

ii. The least contaminant volume spans within the range of -62 to 19.9 mg/l while the highest contamination spans with the range of 316.9 to 359 mg/l

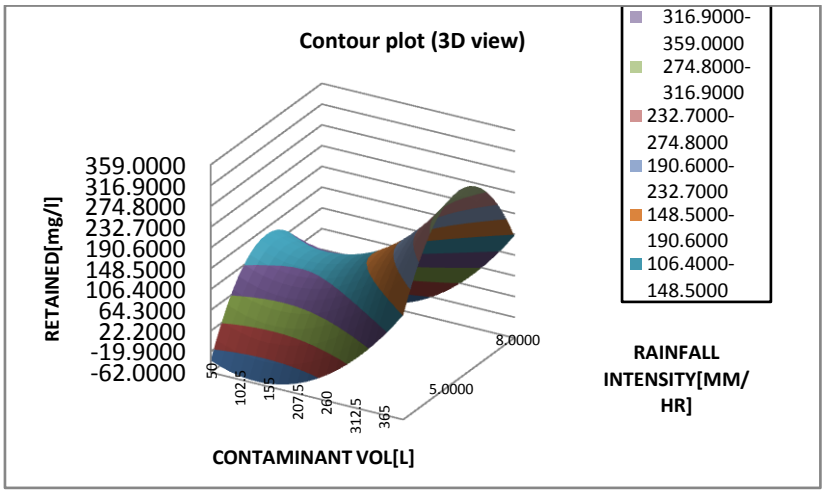

Figure 5.Contour plot (3D view)

Discussion of the result in figure 5

i. Figure 5 showed the 3D view of the developed model.

ii. The least contaminant volume spans within the range of -62 to 19.9 mg/l while the highest contamination spans within the range of 316.9 to 359 mg/l (Akpan et al., 2022).

iii. The contour plot showed the highest and lowest leached concentration with a green and blue colour respectively. See the 3D view of the contour plot in figure 5 for more details.

3.4 RETAINED CONCENTRATION MODEL

The retained concentration model developed and presented below showed that contaminant volume had the highest coefficient compared to the rainfall intensity.

RC = 138.41111+92.24833 Cv -0.88167* RI +89.00833* Cv ^2-172.19167* RI ^2-1.61000* Cv * RI 1*

Where *Cv*= contaminant volume, *RI*= Rainfall intensity, *RC*= Retained Concentration

Discussion of the result in equation 1

i. The retained concentration model presented in equation 1 showed that contaminant volume had the highest coefficient of 92.25 compared to the rainfall intensity of 0.88.
ii. This implies that zero tolerance to diesel spill will prevent impacting on the groundwater quality (Richard, John, Sarah, Lawrence, Jackson, Matthew, Julianne, Sandro and Dale, 2017) and (Zock, 2017).

3.5 MODEL VALIDATION

The model was validated using Pearson's product moment correlation coefficient R. The similarity between the actual and predicted retained concentration showed that good relationship exist with the retained concentration clustered around the trend line given a line of best fit with a coefficient of 0.9501 as shown in Figure 6 .

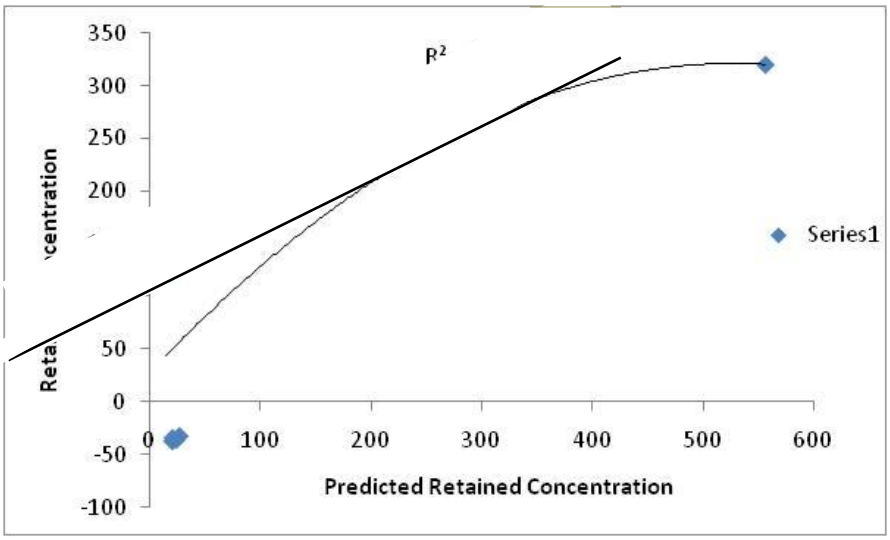

Figure 6. Relationship between the actual and predicted retained concentration

Discussion of the result in figure 6

i. The model was validated using Pearson's product moment correlation coefficient R.
ii. The relationship between the actual and predicted retained concentration showed that a good relationship exist between them and with the retained concentration clustered around the trend line given a line of best fit with a correlation coefficient of 0.95 shown in Figure 6.
iii. This implies that the developed retention model can adequately predict the retention of diesel in unsaturated soil zone when ever spill occur (Ugwoha et al., 2016) and (Chegenizadeh and Hamid, 2018).
iv. More so, the correlation matrix between contaminant volume, rainfall intensity and the retained concentration showed that rainfall intensity has a weak correlation of 0.0043 with the retained concentration while a better correlation of 0.45 exist between the contaminant volume and the retained concentration (Akpan et al., 2022).

IV. CONCLUSION

Generally, the concentrations of TPH retained increases with increased contaminant volume and decreases with increased rainfall intensity as shown in Table 1.This implies that more diesel will be retained in the soil with increase diesel spill and less diesel will be retained with increased rainfall intensity due to the soil k/d factor (Yang, Yang, Duand Lei, 2018).

The standardized coefficient of the contaminant volume, contaminant vol^2 and rainfall intensity^2 of 0.5, 0.25 and -0.5 respectiveley should be taken more seriously in terms of retain concentration of diesel spill because they are higher compared to rainfall intensity and contaminant vol * rainfall intensity as shown in Figure 1. Hence, since the standardized coefficient of the contaminant volume is the highest at 0.25, it implies that increase contaminant volume of the spilled diesel will result in increase quantity of retained diesel concentration in the soil. figure 1 also showed that, rainfall intensity is approximately zero, this implies that increased rainfall intensity will result in decreased amount of retained concentration. Hence rainfall intensity can be used to reclaim contaminated soil (Amie-Ogan et.al. (2022).

Figure 2 showed that an increase in contaminant volume from 110ml to 400ml results in a simultaneous increase in the retained concentration from 100mg/l to 800mg/l. It means that an increase in contaminant volume will impact more on groundwater contamination than change rainfall intensity (Obire and Nwaubeta, 2018).

Figure 3 showed that increase in rainfall intensity will initially cause an increase in retained diesel concentration, however at the passage of time further increase in rainfall intensity will result to a simultaneous decrease in the retained diesel concentration. This implies that the concentrations of TPH retained decreases with increased rainfall intensity (Jian, Omar, Saeed, and Sokrates, 2018).

The 2D and 3D models in figure 4 and five implies that zero tolerance to diesel spill will prevent impacting on the groundwater quality (Richard, John, Sarah, Lawrence, Jackson, Matthew, Julianne, Sandro and Dale, 2017) and (Zock, 2017).

The correlation coefficient of 0.95 was obtained using Pearson's product moment correlation coefficient method as shown in Figure 6. This implies that the developed retention model can adequately predict the retention of diesel in unsaturated soil zone following release (Ugwoha et al., 2016) and (Chegenizadeh and Hamid, 2014).

More so, the correlation matrix between contaminant volume, rainfall intensity and the retained concentration showed that rainfall intensity has a weak correlation of 0.0043 with the retained concentration while a better correlation of 0.45 exist between the contaminant volume and the retained concentration.

V. RECOMMENDATION

The following were recommended.

Niger Delta Development Commission should financially support and encourage creative innovations like the fabricated rainfall simulator, lysometer and auger rig undisturbed soil collector since it is resourceful in simulating field experiments

Khana Local government in alliance with national oil spill detection regulation agency(NOSDRA) should sponsor a bill and implement the developed diesel leached concentration model as it will help to optimally reclaim oil spilled land.

VI. CONTRIBUTION TO KNOWLEDGE

Most studies involving petroleum hydrocarbons describe the impact, fate and transport of diesel in soil and groundwater. This research developed a model to predict the retention of diesel in silty clay soil that is common in Bori region of the Niger delta where most oil spill occurs. The best containment technique for cleanup of diesel contaminated soil in Ogoni land is obtainable.

Necessity is the mother of invention, this research resulted in adaptive creative innovations that include innovations like the fabricated rainfall simulator, lysometer and auger rig undisturbed soil collector is useful in simulating field experiments. This research work encourages adaptive creative innovations and entrepreneurship development.

This research work agrees with the implementation of environmental management system as per clause 5, 6,7, 8,9 and 10 of ISO14001:2015.

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PLATES

Plate 1. Installation of the fabricated auger rig undisturbed soil collector before soil collection.