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

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ABSTRACT
Water-oil fluid interaction in soil possess problems to plants, animals, humans and impacts so much on environmental aspects.. This research is aimed at modeling the transportation of diesel spill in Niger Delta soil. The objectives are to monitor the movement of diesel at given soil depths, different contaminant volumes and rainfall intensities, and develop a model that can describe the transportation of diesel in unsaturated soil zone at different release 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 models for leached total petroleum hydrocarbon (TPH) following release 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. Several creative innovations which include rainfall simulator, lysimeter with a mesocosm and an auger rig soil collector were fabricated and validated. 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. The results showed variations in the transport of diesel with the independent and constant variables. The results further showed that the TPH ranged from 633.91m1 to 1.58E+05m1 with the lowest washout concentration of 1.52E+05m1 obtained when contaminant concentration was 50m1 at rainfall intensity of 10mm/hr and highest washout concentration of 2672.89m1 obtained when contaminant volume was 400m1 at rainfall intensity of 7.5mm/hr. The model was used to fit the transportation of diesel in silt-clay soil after accidental release with correlation coefficient of 0.9407. Federal ministry of environment and Niger Delta Development Commission should financially support and encourage creative innovations like the fabricated rainfall simulator, lysometer and auger rig undisturbed soil collector since they are resourceful in simulating field experiments.

KEYWORD: Transportation model, Diesel fuel, Niger delta, Gas chromatography, Sieve analysis, Leached concentration, Contaminant volume, Rainfall intensity, Soil depth.

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I. INTRODUCTION

In the views of Collins (2018) , Niger Delta, located down the Southern divide of Nigeria, comprises mainly of states trans-divided by the river Niger and its tributaries. Bori, is located at Latitude 4°40′34″N and Longitude 7°21′54″ with elevation of 18 m (59 ft) high above sea level (Ukaji and Solomon, 2014). Oil spill contamination in Bori is a serious threat to livelihood due to poor soil geological formation (Kola-Olusanya and Mekuleyi,2018) and (Akpotor.,2019). The UNEP report (2011) and the works of Amie-Ogan, Petaba, Leyira, Nwikina, Philip-Kpae, and Akpan, (2022) showed that huge population of native indigence and immigrant settles in the land. The establishment of Rivers State polytechnic, Bori accounts for the large settlement of people compared to other areas in Ogoni land. The sources of drinking water are surface water and unconfined aquifer (United Nation Environmental Protection Agency (UNEP) report, 2011). Bori is formally referred to as the food basket of Niger Delta (Yakubu,2017).The indigenes are mainly fishers and farmers by occupation (Akpotor.,2019; Bartels, Eckstein, Waller, Wiemann, 2019), with fragile vegetation and ecosystem (Refugee Review Tribunal Australia, 2007). These are the reasons why oil spill in the land spell doom and catastrophe (Pegg and Zabbey ,2013) and (Petaba, Badom, Pepple, Amie-Ogan, Nwikina, and Akpan, 2022). The citizens are likely to suffer from chronic cancerous and mutagenic effects within the nearest 15- 20 years (Ihesinachi and Eresiya ,2014). Crops are dying and some have even gone into extinction (Oshienemen, Amaratungaa and Richard ,2018). Her rich farm produce are no longer yielding well (Senewo, 2015). Some see foods have gone into extinctions (Kadafa, 2012) and (Amie-Ogan et al., 2022). Hence there is need to reclaim the oil spilled land (Fentimana and Zabbey , 2015). All of these account for the choice of using Bori as a case study for this research.

This research is focused on observing the transportation of diesel in a typical “Ogoni-Land” (soil) following its release on the ground surface. Various materials, approaches and measures were employed to obtain the aim of this research work. TPH test was done to obtain amount of pollution in the soil at the Petroleum Laboratory in Rivers State University. The samples were clearly tagged, indicating location of collection.

The soil and water utilized in the experiment were first analyzed before contamination to determine the background concentration of diesel. Soil and water with zero contaminants represent the control experiment. After contaminating the soil and simulating rainfall, the effluents were collected, noted as leached, and tested for TPH. Model of the transportation of diesel following release on ground surface was developed using RSM software.

The desel used for this research was obtained from a fuel station at Bori. It was obtained by fractional distillation (Dudek , Kancir , and Oye, 2017). Octane reacts exothermically releasing 44000 joules of energy for every gram of C_8H_{18} burned (Diwu, Liu, You, Ghou, Qiao, and Zhao, 2018) as shown in equation 1 .

$$C8H18 + 12.5\ O_2 \rightarrow 8\ CO_2 + 9H_2O \qquad 1.$$

The air produced is 21% oxygen and 79% nitrogen. The soil used in this study was obtained from Ogoni land, Bori the capital of Khana Local Government Area of Rivers State. Several factors such as properties of the diesel (Priyanka, Bhatia, Jaswinder, Rashmita (2015), volume of the diesel, subsurface flow conditions (Amie-Ogan, Badom, Gbinu, Bob, Gboralo, and Akpan, 2022), duration of release and area of infiltration affected the transport of diesel in the subsurface. Ugwoha, Nwankwo , and Okoronkwo , (2016) reported that kerosene transport in coarse textured soils will be more than fine textured soil. The works of Yang, Du, and Lei (2018) showed that a higher Kd is obtained when the adsorption coefficient (Kd) of smaller aggregates is determined, based on the soil properties.

II. MATERIALS AND METHODS

The materials used for this research includes, rain fall simulator, lysometer with a mesocosm., diesel, auger rig undisturbed soil collector, soil samples and RSM Excel Stat. Program (Amie-Ogan et al., 2016) and (Akpan, Bob, Badom, Pepple, Nwiyor, and Ndam, 2022) .

2.1 Experimental Setup

In the views of Petaba et al., (2022) s simple laboratory experiment was done to model the transport of diesel in sandy soil. The experimental setup used was designed and reported by Ugwoha et al. (2016) with little modifications. An auger rig undisturbed soil collector was used to collect the soil samples. First the site was cleared and the vegetable soil removed. The auger rig was properly mounted at the proposed location. The soil collector was firmly position and anchored to the link between the base of the hammer and the top of the soil collector. The verticality of the auger rig was ensured using a spirit level as shown in Plate 1. The collector was driven using 20kg hammer to a 1000mm depth. The auger rig was subsequently disassembled to remove the collector undisturbed. The collector was properly removed and its base guided with a net as shown in Plate 1.

Next the soil collector that served same purpose of a mesocosm was properly inserted in an opening on a well fabricated table where the calibrated rain fall simulator was installed as shown in Plate 1. It was clamped using fabricated galvanized steel clipped at a marked soil collector such that a 10000mm empty vacuum can be filled with the simulated rain fall. The remaining 300mm void in the soil collector was kept to prevent overflow of accumulated rainfall simulated water. The base of the mesocosm was properly guided also to prevent erosion and filter washout.

More so, water was pumped into a 1000liter thank that was used to mimic rainfall at varying intensity of 5mm/h, 7.5mm/hr and 10mm/hr as shown in Plate 1. After calibrating the simulated rainfall for a calculated volume of water based on the intensity, the valve was turned on. Varying proportions of diesel were also spilled into the mesocosm before turning on the calibrated rainfall simulator.

After contaminating and simulating rainfall on the entire soil, the washouts were properly collected after 1hr 45 minutes for each experiment. The volume of the washouts were recorded and stored in cold environment with a 1 liter plastic container at the end of each experiment to shield it away from any form of radiations

The samples were conveyed to Rivers State University petroleum laboratory for TPH test. The diesel was carefully extracted from the well labeled water samples using hexane as shown in Plate 1. The washouts were properly mixed with hexane in the ratio of 1:10. The mixture was properly agitated in a sealed container and purred in a well clamped separating funnel as shown in Plate 1. The hexane was properly discarded from the mixture in the separation funnel due to its less density. The extracted diesel was injected into a gas chromatography to determine it TPH.

2.2 Analysis of Sample

Total petroleum hydrocarbons (TPH) was analyzed with GC-FID methods using a gas chromatography.

2.3 Extraction of Hydrocarbon in Water

Hexane($C_6\ H_{14}$) was used as the reagent for extraction because it is the first liquid in the HC series and thus making it a good bonding agent for the extraction since its level of evaporation is at its minimal. The volume of extraction was determined by the material. The procedure for the extraction started with; washing and drying all the materials used to avoid water. 50ml of water and extraction solvent (Hexane) were poured into a washed and dried bottle, Agitated for 30mins, poured into a separating funnel and allowed to stand for 1hr. The tap was opened to separate the two elements, the water was thrown away while the remaining samples (solvent) were well arranged and labeled in a tube for identification as shown in plate 1.

2.5 Gas Chromatography

The collected sample extract was injected into a Gas Chromatography Flame Ionization Detector (GC-FID). 1ul of concentrated petroleum hydrocarbon sample extract was injected through a rubber septum into the column by means of hypodermic syringe. The various fractions of the aliphatic compounds (C_8-C_{40}) were automatically detected as it emerges from the column. The results were expressed in mg/l.

2.6 Response Surface Method (Experimental Design)

XLSAT software using RSM method of a full factorial design with 3 levels was used to generate the number of observation or experimental runs required to develop a transport model. It was used to optimize the output variables which in this case were retained and leached concentrations. The input variables were soil height (1000mm), diesel contaminant (50ml, 225ml and 400ml) and rainfall intensity ranging from 5mm/hr to 10mm/hr; since the soil depth is constant it was thus neglected. Nine observations/experimental runs were generated as presented in Table 4.4.

2.7 Model Assumptions

The following assumptions were considered in development of the model.

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

III. RESULTS AND DISCUSSION

The results and discussions are presented bellow.

3.1 Leached concentration of total petroleum hydrocarbons (tphs) from water sample collected

The leached concentration through a constant soil depth of 1000mm at varying rainfall intensities and contaminant concentrations are stated in Table 4.4 below.

Table 1. Washout Concentration of TPH for various rainfall intensities and contamination volumes

Observation	Sort order	Run order	Repetition	Contaminant vol	Rainfall intensity	Leached
Obs1	1	1	1	50	5	633.91
Obs2	2	2	1	225	5	739.23
Obs3	3	3	1	400	5	1661.1
Obs4	4	4	1	50	7.5	1.19E+04
Obs5	5	5	1	225	7.5	661.86
Obs6	6	6	1	400	7.5	2673.89
Obs7	7	7	1	50	10	1.52E+05
Obs8	8	8	1	225	10	8.30E+04
Obs9	9	9	1	400	10	1.58E+05

Discussion of the result in table 1

i. Table 1 presented the results of leached concentration through a constant soil depth of 1000mm at varying rainfall intensities and contaminant concentrations.

ii. Generally, the concentration of leached TPH initially decreases with increased contaminant concentration; however, at the passage of time, increase in contaminant volume from 50ml to 400ml resulted in a simulations increase in leached concentration from 633.91mg/l to 739.23mg/l.

iii. The result also showed that the leached concentration increases from 633,91mg/l to 1.58E+05mg/l with simultaneous increase in rainfall intensity from 5mm/hr to 10mm/hr.

iv. The result in table 1 inferred that the TPH ranged from 633.91mg/1 to 1.58E+05mg/1 with the lowest washout concentration of 1.52E+05mg/1 obtained when contaminant concentration was 50m1 at rainfall intensity of 10mm/hr and highest washout concentration of 2672.89m1 obtained when contaminant volume was 400m1 at rainfall intensity of 7.5mm/hr.

v. The results in table 1 also showed that the concentration of leached TPH initially decreases from 1.19E+04mg/l to 661.86mg/l with increased contaminant volume from 50ml to 225ml; however at the passage of time the leached concentration increases from 661.86mg/l to 1.58E+05mg/l with an increase in contaminant volume and rainfall intensity of 50ml to 400ml and 5mm/hr to 10mm/hr respectively.

3.2 Standardization Coefficient of Leached Diesel Concentration

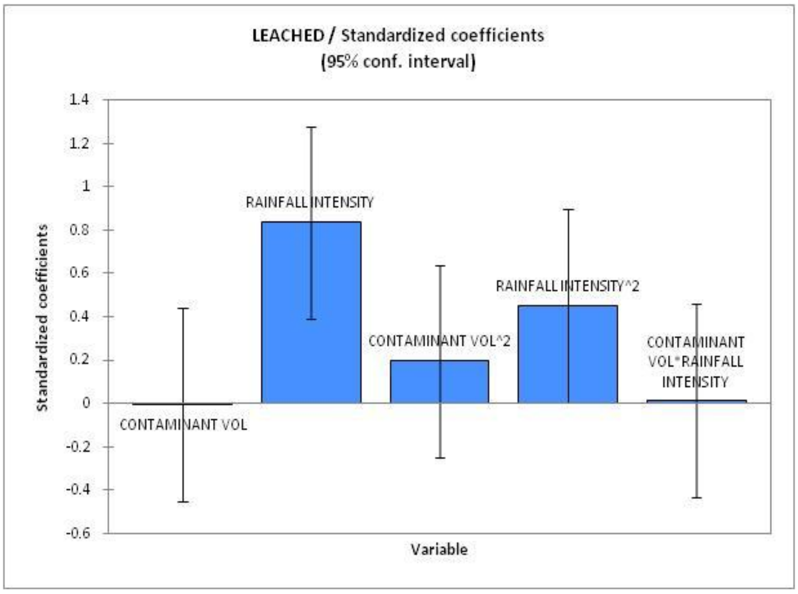

Figure 1.Wash out / Standardized coefficients

Discussion of the result in figure 1

i. Figure 1. Showed that rainfall intensity has higher standardized coefficient of 0.82. Hence would be considered as more important standardized coefficient compared to other coefficient presented when developing the model.
ii. Since the rainfall coefficient is the highest at 0.82, it means an increase in rainfall intensity will equally increase the rate of leached concentration.
iii. The leached concentration of the diesel components will be slightly affected by the contaminant volume since its standardized coefficient is approximately zero.
iv. More concern should be allotted to rainfall intensity, contaminant volume^2 and rainfall intensity^2 sequel to their higher standardized coefficient of 0.82, 0.2 and 0.6 respectively as shown in Figure1.
v. The leached concentration of diesel varies with different rainfall intensities. It increases with increased rainfall intensity and contaminant volume^2.
vi. Generally, the bar charts in figure 1 showed that the leached concentration of the diesel components were affected more at the highest rainfall intensity.
vii. Hence diesel spills on soil are likely to have more groundwater contamination impacts during period of high rainfall intensity and contaminant volume (Olaifa and Osuagwu, 2017).

3.3 Relationship between Leached Concentration and Contaminant Volume

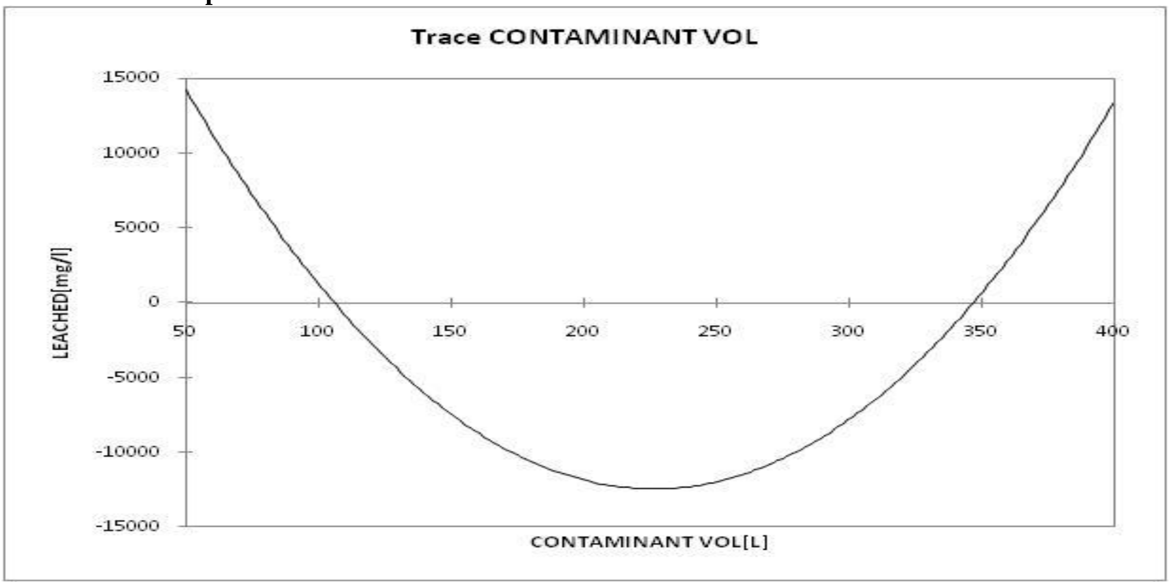

Figure 2.Leached Concentration through varying diesel trace contaminant volumes

Discussion of the result in figure 2

i. Figure 2 showed that increase in contaminant volume results in a simultaneous decrease in leached concentration.
ii. At the passage of time, at contaminant volume of 225ml a further increase in contaminant volume results in a simultaneous increase in leached concentration.
iii. Generally, the bar charts in figure 2 showed that the leached concentration of diesel varies from -10,000mg/l to 15000mg/l with different rainfall intensities that ranges from 5mm/hr to 10mm/hr.

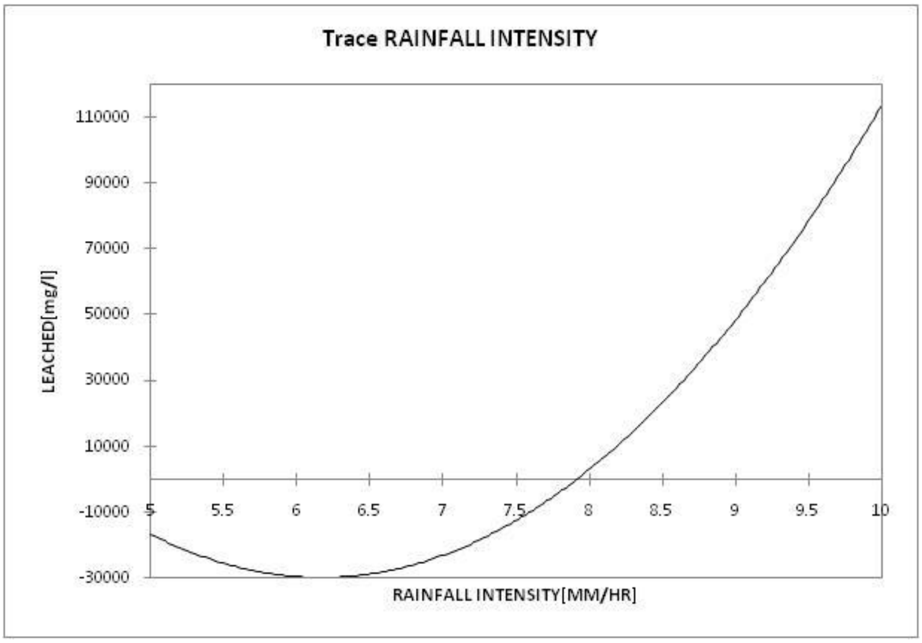

Figure 3.Leached Concentration through varying rainfall intensites

Discussion of the result in figure 3

i. Figure 3 showed an initial decreased in the leached concentration from -2000mg/l to -3000mg/l when rainfall intensity increases from 5mm/hr to 6.2mm/hr. The decrease is caused by the high rate of unsaturation of the soil, permeability and infiltration constant.

ii. Figure 3 also showed that an increase in rainfall intensity from 6.2mm/hr to 10mm/hr results in a simultaneous increase in the leached concentration from -3000mg/l to 110000mg/l

iii. Further increase in rainfall intensity from 10mm/hr and above will equally result in a simultaneous increase in leached concentration from 110000mg/l to higher volume of leached concentration

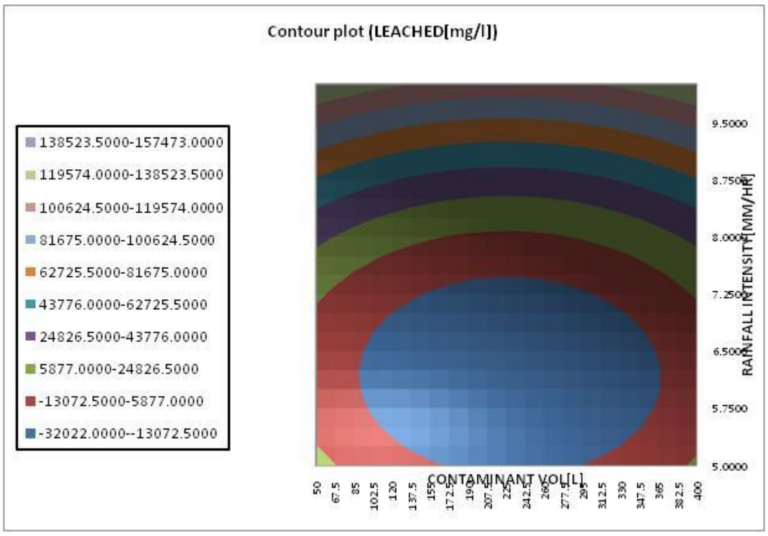

Figure 4.Contour plot (Wash out [mg/l])

Discussion of the result in figure 4

i. Figure 4 showed the relationship between contaminant volume and rainfall intensity.

ii. Contaminant volume is lowest within the range of 0.00- 13072.5mg/l and highest within the range of 138523.5 – 157473.0 mg/l.

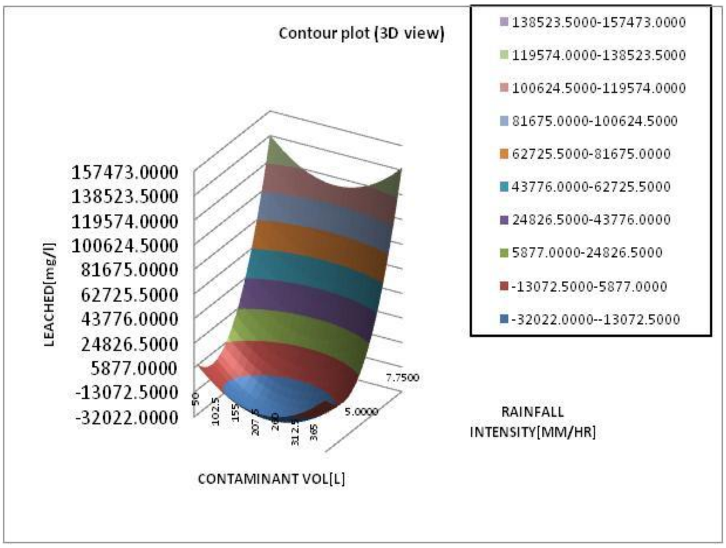

Figure 5.Contour plot (3D view)

Discussion of the result in figure 5
It shows a 3D view of the developed model.

i. Figure 5. showed the relationship between contaminant volume and leached concentration.
ii. Contaminant volume is lowest within the range of 0.00- 13072.5mg/l and highest within the range of 138523.5 – 157473.0 mg/l.

3.4 Leached Concentration Model
In view of the leached concentration model developed, it was observed that rainfall intensity had the highest coefficient compared to the contaminant volume.

LC = -12458-432.07000 Cv +64936* RI +26287* Cv ^2+60880* RI ^2+1136* Cv * RI* 2
Where, *Cv*= contaminant volume, *RI*= Rainfall intensity, *LC*= Washout Concentration

Discussion of the result in equation 2 above

i. The leached concentration model developed showed that rainfall intensity had the highest coefficient of 172.19167 compared to contaminant volume that had 92.24833.
ii. Hence, diesel spills with higher contaminant volume will impact more in groundwater following release on clay soil (Bautista, and Rahman, 2016) (Sarbatly, Kamin and Krishnaiah, 2016).
iii. The leached concentration model developed showed that rainfall intensity had the highest coefficient of 172.19167 compared to contaminant volume that had 92.24833.
iv. Hence prevention of diesel spill will reduce its impact on environmental aspects (groundwater) and it agrees with the thought of Aniefiok, Thomas, Clement, Ekpedeme and Iniemem (2018).

3.5 Model Validation

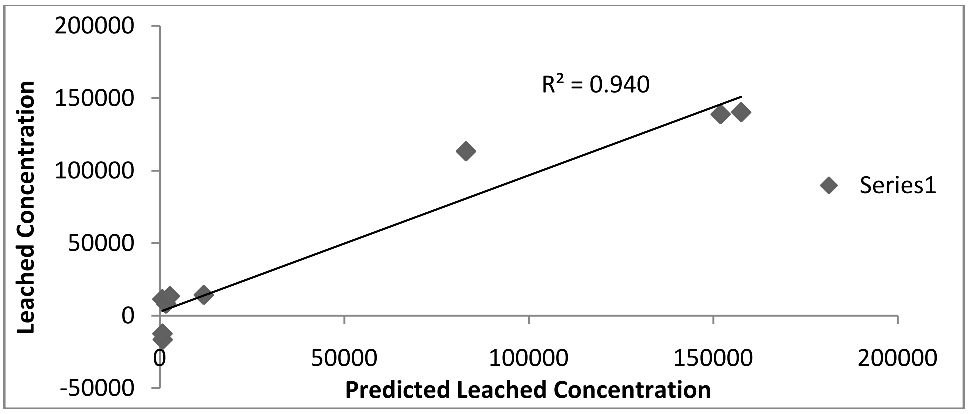

Figure 6. Relationship between the actual and predicted retained concentration

Discussion of the result in figure.6

i. The model was validated using Pearson's product moment correlation coefficient R.
ii. There is a good relationship between the actual and predicted leached concentration.
iii. The leached concentrations clustered around the trendline giving a line of best fit with a correlation coefficient of 0.94.
iv. This implies that the model can adequately predict the leached concentration of diesel in the unsaturated zone following a spill (Ugwoha et al., 2016).
v. More so, the correlation matrix between contaminant volume, rainfall intensity and the leached concentration showed that rainfall intensity has a strong correlation of 0.8355 with the leached concentration while a weak correlation of 0.0056 exist between the contaminant volume and the leached concentration.
vi. This implies that an increase in rainfall intensity will aid the impact of diesel on groundwater contamination as per Brakorenko, and Korotchenko (2016).

IV. CONCLUSION

Generally, the concentration of leached TPH initially decreases with increased contaminant concentration; however, at the passage of time, increase in contaminant volume from 50ml to 400ml resulted in a simulations increase in leached concentration from 633.91mg/l to 739.23mg/l. The result also showed that the leached concentration increases from 633,91mg/l to 1.58E+05mg/l with simultaneous increase in rainfall intensity from 5mm/hr to 10mm/hr. The results in table 1 also showed that the concentration of leached TPH initially decreases from 1.19E+04mg/l to 661.86mg/l with increased contaminant volume from 50ml to 225ml; however at the passage of time the leached concentration increases from 661.86mg/l to 1.58E+05mg/l with an increase in contaminant volume and rainfall intensity of 50ml to 400ml and 5mm/hr to 10mm/hr respectively.

Generally, the bar charts in figure 1 showed that the leached concentration of the diesel components were affected more by the highest rainfall intensity. More concern should be given to rainfall intensity, contaminant volume^2 and rainfall intensity^2 sequel to its higher standardized coefficient of 0.82, 0.2 and 0.6 respectively. Since the rainfall coefficient is the highest at 0.82 as shown in figure 1 it means an increase in rainfall intensity will equally increase the rate of leached concentration. Hence diesel spills on soil are likely to have more groundwater contamination impacts during period of high rainfall intensity and contaminant volume (Olaifa and Osuagwu, 2017).

Generally, the bar charts in figure 2 showed that the leached concentration of diesel varies from -10,000mg/l to 15000mg/l with different rainfall intensities from 5mm/hr to 10mm/hr. It showed that increase in contaminant volume results in a simultaneous decrease in leached concentration. At the passage of time, at contaminant volume of 225ml a further increase in contaminant volume results in a simultaneous increase in leached concentration (Amie-Ogan et al., 2022).

Figure 3 showed an initial decrease in the leached concentration from -2000mg/l to -3000mg/l when rainfall increases from 5mm/hr to 6.2mm/hr. The decrease is caused by the high rate of unsaturation of the soil, permeability and infiltration constant. It also showed that an increase in rainfall intensity from 6.2mm/hr to 10mm/hr results in a simultaneous increase in the leached concentration from -3000mg/l to 110000mg/l. Further increase in rainfall intensity from 10mm/hr and above will equally result in a simultaneous increase in leached concentration from 110000mg/l to higher volume of leached concentration

Figure 4 and 5 showed the relationship between contaminant volume and rainfall intensity. Contaminant volume is lowest within the range of 0.00- 13072.5mg/l and highest within the range of 138523.5 – 157473.0 mg/l.

Figure 5. showed that rainfall intensity had the highest coefficient of 172.19167 compared to contaminant volume that had 92.24833. Hence, diesel spills with higher contaminant volume will impact more in groundwater when ever spill occur on clay soil (Bautista, and Rahman, 2016) (Sarbatly, Kamin and Krishnaiah, 2016). Prevention of diesel spill will reduce its impact on environmental aspects (groundwater) and it agrees with the thought of Aniefiok, Thomas, Clement, Ekpedeme and Iniemem (2018).

The model was validated using Pearson's product moment correlation coefficient R. There is a good relationship between the actual and predicted leached concentration. The leached concentrations clustered around the trendline giving a line of best fit with a correlation coefficient of 0.94. This implies that the model can adequately predict the leached concentration of diesel in the unsaturated zone following release (Ugwoha et al., 2016) and (Petaba, et al. , 2022).

Moreso, the correlation matrix between contaminant volume, rainfall intensity and the leached concentration showed that rainfall intensity has a strong correlation of 0.8355 with the leached concentration while a weak correlation of 0.0056 exist between the contaminant volume and the leached concentration. This implies that an increase in rainfall intensity will aid the impact of diesel on groundwater contamination as per Brakorenko, and Korotchenko (2016) and (Akpan, et al. , 2022)..

V. RECOMMENDATION

The following are 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 implement the developed diesel transportation concentration model as it will help to fulfill the requirements of ISO 14001:2015 standards.

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 transport and 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.

REFERENCES

[1]. Akpan P. P., Bob D. M. A., Badom F. Z., Pepple M. S., Nwiyor P. S. and Ndam E. (2022).Influence of Varying Rainfall Intensities on Spilled Diesel Transport in Bori-Ogoni Soil, International Journal of Engineering Research and Applications (IJERA) , 12 (1),63-69, ISSN: 2248-9622 , www.ijera.com

[2]. Akpotor E.(2019) . Crude Oil Exploration and Exploitation In Niger Delta: A Christian Concern *International Journal of Innovative Development and Policy Studies* 7(2),38-49, http://seahipaj.org/journals-ci/june-2019/IJIDPS/full/IJIDPS-J-5-2019.pdf

[3]. Amie-Ogan T. G., Badom F. Z.,Gbinu K. S., Bob D. M. A., Gboraloo W. A., and Akpan P. P. (2022). Influence of Varying Contaminant Volume on Diesel Transport in Khana Soil, International Journal of Engineering Research and Applications (IJERA) , 12 (1), 56-62 , ISSN: 2248-9622 , www.ijera.com

[4]. Amie-Ogan T. G., Petaba L. D., Leyira F. G., Nwikina B. B., Philip-Kpae F. O., and Akpan P. P. (2022). Diesel Spill Retention Modeling Of Niger Delta Soil", International Journal of Engineering Research and Applications (IJERA) , 12 (1):50-55, ISSN: 2248-9622 , www.ijera.com.

[5]. Aniefiok E. I. , Thomas A. H., Clement O. O., Ekpedeme R. A. and Iniemem J. I. (2018). Petroleum Hydrocarbons Contamination of Surface Water and Groundwater in The Niger Delta Region of Nigeria, *Journal of Environment Pollution and Human Health*. 2018, 6(2), 51-61. DOI: 10.12691/jephh-6-2-2.

[6]. Bartels A., Eckstein L., Waller N.,and Wiemann D. (2019). Post Colonialism and Ecology. In: Postcolonial Literatures in English. J.B. Metzler, Stuttgart https://link.springer.com/chapter/10.1007/978-3-476-05598-9_11

[7]. Bautista, H. and Rahman, K. M. (2016). Effects of Crude Oil Pollution in the Tropical Rainforest Biodiversity of Ecuadorian Amazon Region. *Journal of Biodiversity and Environmental Sciences.*8 (2), 249–254.

[8]. Brakorenko N.N. and Korotchenko T.V. (2016). Impact of Petroleum Products on Soil Composition and Physical-Chemical Properties, IOP Conference Series: Earth and Environmental Science, 33 (1).

[9]. Collins E. (2018). Oil Exploration in the Niger Delta: Its' Gains and Loss, IIARD International *Journal of Geography and Environmental Management*, 4(3),24-31 http:www.iiardpub.orgIIARD

[10]. Diwu P., Liu T., You Z., GHou G., Qiao R., and Zhao L. (2018). Study on Pulse Characteristic of Produced Crude Composition in CO2 Flooding Pilot Test. Journal of Geofluids. Article ID 2968629, 5 pages https://doi.org/10.1155/2018/2968629.

[11]. Dudek M., Kancir E., and Oye E. (2017). Influence of the Crude Oil and Water

Compositions on the Quality of Synthetic Produced Water,*Energy& Fuels 31* (4), 3708-3716.DOI: 10.1021/acs.energyfuels.6b03297.

[12]. Fentimana A., and Zabbey N. (2015). Environmental Degradation and Cultural Erosion in Ogoniland: A case Study of The Oil Spills in Bodo, Science Direct, 2(4),615-624 https://doi.org/10.1016/j.exis.2015.05.008

[13]. Kadafa, A. A.(2012). Environmental Impacts of Oil Exploration and Exploitation in the Niger, Global Journal of Science Frontier Research Environment and Earth Sciences,12 (3).

[14]. Kola-Olusanya A. and Mekuleyi G. O.(2018). The Eco-Economics of Crude Oil Exploration in Nigeria, The Political Ecology of Oil and Gas Activities in the Nigerian Aquatic Ecosystem,*Science direct*, .https://www.sciencedirect.com/topics/earth-and-planetary-sciences/crude-oil.

[15]. Olaifa, E. and Osuagwu, E. (2017). *Effects of Oil Spills on Fish Production in the Niger Delta of Nigeria.*In: CUCEN 2017, Covenant University, Ota. http://eprints.covenantuniversity.edu.ng/id/eprint/10339.

[16]. Oshienemen N.A., Amaratungaa D., and Richard P.H.(2018). Evaluation of the Impacts of Oil Spill Disaster on Communities and Its Influence on Restiveness in Niger Delta, Nigeria, Science Direct: Procedia Engineering, 212, 1054-1061. https://doi.org/10.1016/j.proeng.2018.01.136

[17]. Pegg S. and Zabbey N. (2013). Oil and water: The Bodo Spills and The Destruction of Traditional Livelihood Structures in The Niger Delta, *Community Development Journal*, 48, (1), 391–405, https://doi.org/10.1093/cdj/bst021 https://academic.oup.com/cdj/article-abstract/48/3/391/310555

[18]. Petaba L. D., Badom F. Z., Pepple M. S., Amie-Ogan, T. G. , Nwikina B. B., and Akpan P. P. (2022). Diesel Spill Transportation Modeling Of Niger Delta Soil, International Journal of Engineering Research and Applications (IJERA) , 12 (1),42-49, ISSN: 2248-9622 , www.ijera.com

[19]. Priyanka G., Bhatia M. S., Jaswinder K., and Rashmita S.(2015). Dependence on Petroleum Products, *Delhi Psychiatry Journal* 18(1), medind.nic.in/daa/t15/i1/daat15i1p221.pdf.

[20]. Refugee Review Tribunal AUSTRALIA (2007). RRT Research Response Research Response,NGA32636 https://www.refworld.org/pdfid/4b6fe2b5d.pdf

[21]. Sarbatly R.; Kamin, Z. and Krishnaiah D. (2016). A Review Of Polymer Nanofibres By Electrospinning and Their Application in Oil-Water Separation For Cleaning Up Marine Oil Spills. *Marine Pollution Bulletin*.106, 8–16. doi:10.1016/j.marpolbul.2016.03.037.

[22]. Ugwoha E, Nwankwo C and Okoronkwo C. (2016). Effect of Soil Type on the Fate of Kerosene Compounds in the Presence of Water and Ethanol. J Environ Stud. 2(1), 8.

[23]. Ukaji D. and Solomon L. (2014).The Effectiveness of Oral Rehydration Therapy in the Treatment of Diarrhea in Children Who Attend Primary Health Care Clinic in Bori, Rivers State, Nigeria. *Advanced Journal of Medical Reports and Reviews,* 2(001), 001-007. https://www.researchgate.net/publication/311799866

[24]. UNEP (2011). UNEP Ogoniland Oil Assessment Reveals Reveals Extent of Environmental Contamination and Threat To Human Lives. https://www.unenvironment.org/news-and-stories/story/unep-ogoniland-oil-assessment-reveals-extent-environmental-contamination

[25]. Yakubu O.H. (2017). Addressing Environmental Health Problems in Ogoni land through Implementation of United Nations Environment Program Recommendations: Environmental Management Strategies, *Journal of Environments* 4 (28), 1-99 https://www.mdpi.com/2076-3298/4/2/28/pdf

[27]. Yang M., Yang Y., Du X. and Lei Y (2018). Fate and Transport of Petroleum Hydrocarbons in Vadose Zone: Compound-specific Natural Attenuation. Water Air and Soil Pollution, 224(3), doi: 10.1007/s11270-013-1439-y.

PLATES

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