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Influence of Varying Contaminant Volume on Diesel Transport in Khana Soil

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ABSTRACT
This research is aimed at monitoring the transportation of diesel fuel spill in Niger Delta soil. The objectives are to contaminate an unsaturated soil at varying contaminant level, simulate rainfall at varying rainfall intensities and monitor the movement of diesel at given soil depths. The presence of diesel contaminant in soil and groundwater table causes problems to plants, animal, humans and the environment. Plants and animals are dying in their numbers and some have gone into extinction. Affected people suffer from acute and chronic diseases such as carcinogens, mutagens and cancer. The method used in generating the experimental design was response surface method which uses two (2) independent variables - contaminant volume and rainfall intensity; and a constant variable known as soil depth. XLSAT software was used to develop the models. The contaminant volumes, rainfall intensities and soil depth used were 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 intensities of 5mm/hr, 7.5mm/hr and 10mm/hr were simulated on the soil. Results showed that the concentration of leached total petroleum hydrocarbon (TPH) initially decreased from 1.19E+04mg/l to 661.86mg/l with increase in contaminant volume from 50ml to 225ml. However, with the passage of time, the leached concentration increased from 661.86mg/l to 1.58E+05mg/l with an increase in contaminant volume from 50ml to 400ml. Hence, diesel spills with higher contaminant volume will impact more on groundwater. It is recommended that NESRA and NORDSRA should ensure zero tolerance to diesel spill in all oil and gas operational industries.

KEYWORD: Diesel fuel, diesel transport, contaminant volume, diesel spill, soil depth

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I. INTRODUCTION

Whenever diesel spill occurs, it is expected that it infiltrates into the soil. When this occurs, some portions of it are expected to infiltrate to the groundwater table while others are retained in the soil. The volume of contaminant in a way influences the quantity of contaminant retained in the soil and the quantity that will further infiltrate to hit the groundwater. Researchers are concerned about this because groundwater pollution is not easy to clean compare to the cost of reclaiming the contaminated soils (Aniefiok, Thomas, Clement, Ekpedeme and Iniemem, 2018). It is important to carry out this research due to the prevalent cases of oil spills in Khana and the concomitant catastrophic effects on plants, animals and humans living in the environment (UNEP report, 2017).

Khana community is an environmental sensitive community. Research shows that the citizens of Khana community are known for farming and fishing (Akpotor ,2019 and Bartels , Eckstein , Waller and Wiemann , 2019). Khana soil is made of Akata, Agbada and Benin formation. It has fragile vegetation and ecosystem with shallow aquifers. Therefore, oil spill in the land spells doom and catastrophe (Pegg and Zabbey , 2013). Diesel spill poses health threat to citizens (Richard, John, Sarah, Lawrence, Jackson, Matthew, Julianne, Sandro and Dale, 2017). Crops and animals have gone into extinction (Oshienemen , Amaratungaa and Richard ,2018). Farm produce are no longer yielding well (Senewo, 2015). Aquatic lives are dying (Kadafa, 2012) and (Olaifa, and Osuagwu, 2017).

This research is focused on observing the transportation of diesel in a typical “Ogoni-Land” (soil) following its release on the ground surface. Diesel fuels are any liquid used in diesel engines

(Khan and Kamal, 2015). Real diesel fuels are mixtures composed of hundreds to thousands of components (Wang and Chen, 2017). The bulk density of peat soil increases with increase in diesel spill and is a major factor that determines the fate and transport of diesel in the soil (Gharedaghloo and Jonathan, 2018). Most soil properties provide important sets of reactions and interactions between soils and petroleum products and it changes the transport of the petroleum products within the soil (Fallah, Shabanpor, Zakerinia, and Ebrahimi, 2015). Several factors such as properties of the diesel (Priyanka, Bhatia, Jaswinder, and Rashmita (2015), volume of the diesel, subsurface flow conditions, time and duration of release, area of infiltration affects the transport of diesel in the subsurface. This research seeks to determine the effect of varying contaminant volumes on the transportation of diesel spill on a typical Khana soil at varying rainfall intensities.

II. MATERIALS AND METHODS

The materials used for this research include: rainfall simulator, lysimeter with a mesocosm., diesel, auger rig undisturbed soil collector, soil samples and RSM Excel Stat. Program.

2.1 Experimental Setup

A simple laboratory experiment was carried out to effectively monitor the effect of varying contaminant volumes when rainfall is simulated on unsaturated khana soil. An auger rig undisturbed soil collector was used to collect the soil samples. Unsaturated soil with a depth of 1000mm was installed in a lysimeter where contamination was done. The lysimeter was equally placed under a rainfall simulator where varying rainfall intensities were simulated on it. 300mm void was kept in the soil collector (mesocosm) to prevent overflow of accumulated simulated rainfall. The base of the mesocosm was properly guided with net to prevent erosion and filter washouts.

More so, water was pumped into a 1000liter tank that was used to mimic rainfall at varying intensities 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 spilled into the mesocosm before turning on the calibrated rainfall simulator.

After contaminating and simulating the entire soil and rainfall, the washouts were properly collected after 1hr 45 minutes for a particular experiment. The volume of the washouts were recorded and stored. The contaminated soil samples were properly mixed after three washouts were collected. 500g of the mixed contaminants were measured and stored. The contaminants (diesel) were properly extracted from washouts and the contaminated soil and were tested for total petroleum hydrocarbon using a gas chromatography.

2.2 Analysis of Sample

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

2.3 Extraction of Hydrocarbon in Water and Soil

Hexane was used as the reagent for extraction because hexane (C_6H_{14}) is the first liquid in the hydrocarbon series, making it a good bonding agent for the extraction since its level of evaporation is at its minimal. The procedure for the extraction started with washing and drying of 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 sample (solvent) was well kept and labeled in a tube for identification as shown in plate 1. Almost the same procedure was used when hydrocarbon was extracted from soil. The soil samples were firstly dried to remove the moisture content, 5g of soil samples were properly weighed using the analytical weighing balance. 50ml of extraction solvent (hexane) was poured into the washed dried bottle for proper mixing with the measured 5g of soil samples. It was agitated for 30mins before separating using the filter papers. The process of filtration was done quickly to avoid the escape of the solution. The soil particles were thrown away while the remaining sample (solvent) was 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 the Gas Chromatography Flame Ionization Detector (GC-FID). 1µl 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}) are 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 three (3) levels was used to generate the number of observations 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 intensities ranging from 5mm/hr to 10mm/hr; since the soil depth is constant it was thus neglected. Nine (9) observations/experimental runs were generated as presented in Table 3.1.

III. RESULTS AND DISCUSSION

The results and discussions are presented below.

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 3.1 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 3.1

i. Generally, the concentration of leached TPH initially decreased with increased contaminant volume. However, with the passage of time, increase in contaminant volume from 50ml to 400ml resulted in a simultaneous increase in leached concentration from 633.91mg/l to 739.23mg/l.

ii. Table 3.1 presented the results of leached concentration through a constant soil depth of 1000mm at varying rainfall intensities and contaminant volumes.

iii. The results infered 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 volume was 50m1 at rainfall intensity of 10mm/hr; and highest washout concentration of 2672.89m1 obtained at contaminant volume of 400m1 at rainfall intensity of 7.5mm/hr.

iv. The results in table 3.1 also showed that the concentration of leached TPH initially decreased from 1.19E+04mg/l to 661.86mg/l with increased contaminant volume from 50ml to 225ml. However; with the passage of time; the leached concentration increased 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.

3.3 Relationship between Leached Concentration and Contaminant Volume

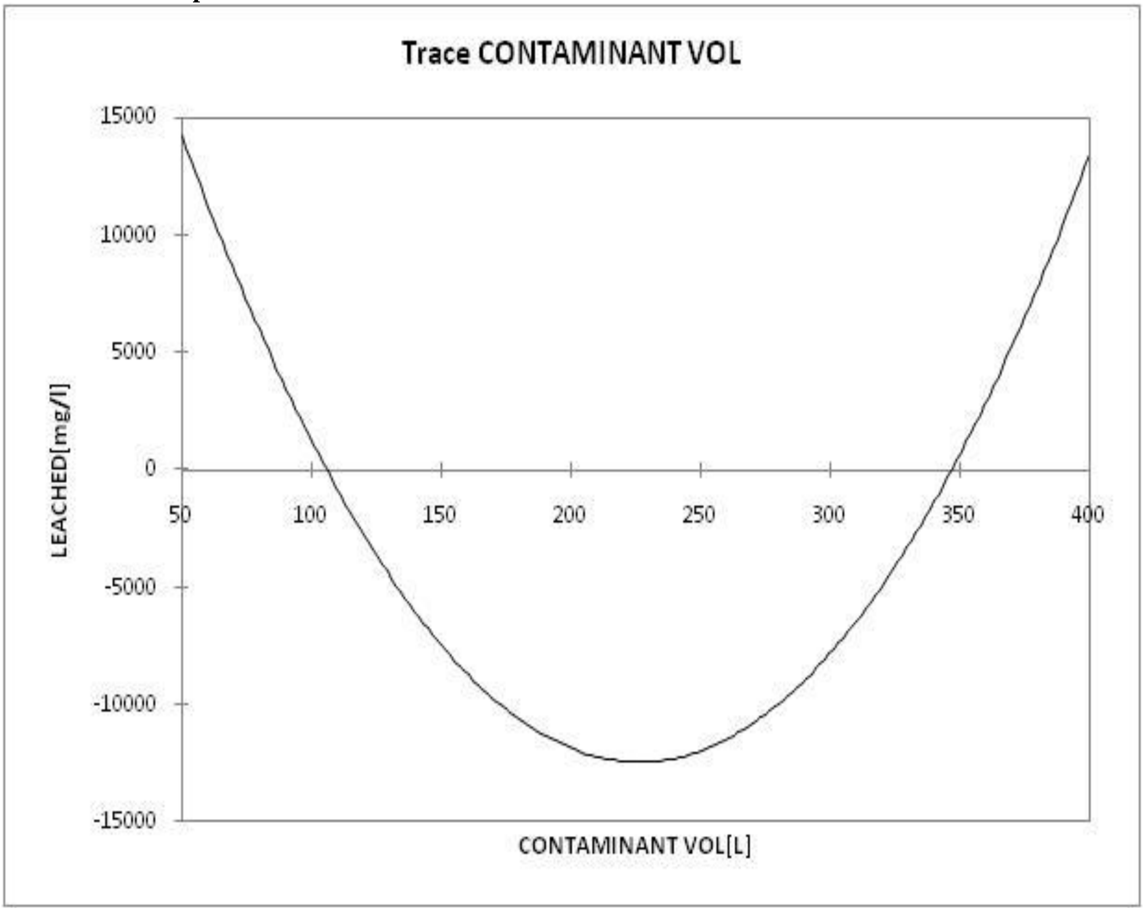

Figure 3.1. Leached Concentration through Varying Diesel Trace Contaminant Volumes

Discussion of the result in figure 3.1

i. Figure 3.1 showed that increase in contaminant volume results in a simultaneous decrease in leached concentration.

ii. With the passage of time, at contaminant volume of 225ml an increase in further contaminant volume resulted in a simultaneous increase in leached concentration.

iii. 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).

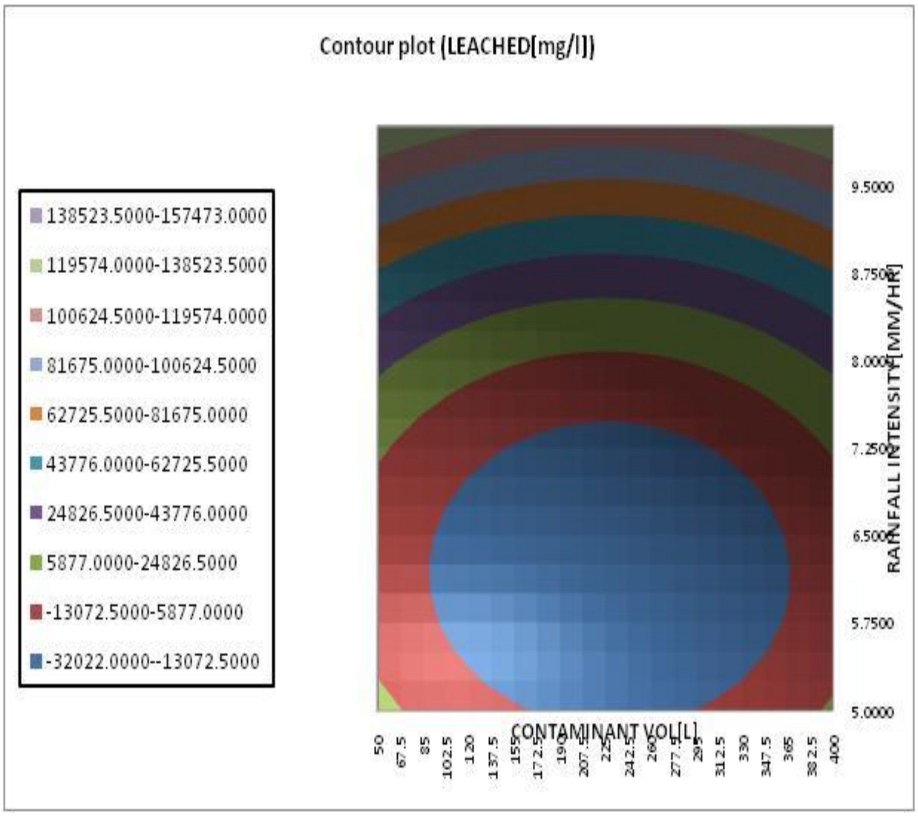

Figure 3.2.Contour Plot (Wash out [mg/l])

Discussion of the result in figure 3.2

i. Figure 3.2 showed the relationship between contaminant volume and rainfall intensity.

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

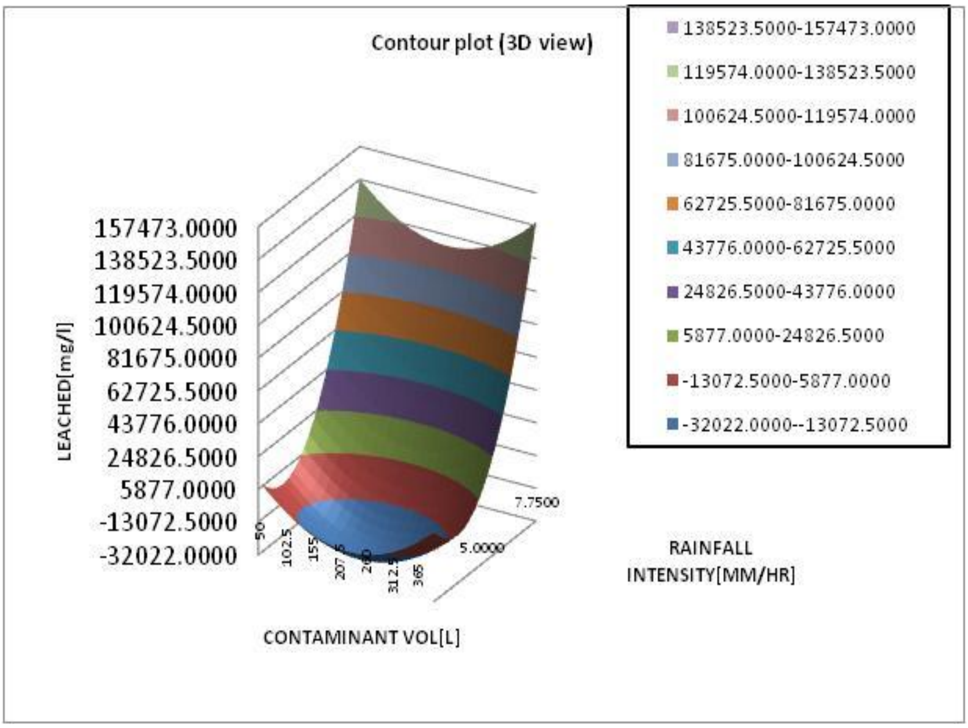

Figure 3.3.Contour Plot (3D view)

Discussion of the result in figure 3.3

It showed a 3D view of the developed model.

i. Figure 3.3. showed the relationship between contaminant volume and leached concentration.
ii. Contaminant volume is lowest within the range of 0.00 and 13072.5mg/l and highest within the range of 138523.5 and 157473.0 mg/l.

IV. CONCLUSION

Generally, the concentration of leached TPH initially decreased with increased contaminant concentration. However, with the passage of time, increase in contaminant volume from 50ml to 400ml resulted in a simultaneous increase in leached concentration from 633.91mg/l to 739.23mg/l.

Table 3.1 presented the results of leached concentration through a constant soil depth of 1000mm at varying rainfall intensities and contaminant concentrations. The results infer 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 volume was 50m1 at rainfall intensity of 10mm/hr, and the highest washout concentration of 2672.89m1 obtained when contaminant volume was 400m1 at rainfall intensity of 7.5mm/hr.

The results in table 3.1 also showed that the concentration of leached TPH initially decreased from 1.19E+04mg/l to 661.86mg/l with increased contaminant volume from 50ml to 225ml. However, with the passage of time, the leached concentration increased from 661.86mg/l to 1.58E+05mg/l with an increase in contaminant volume from 50ml to 400ml. 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).

Figure 3.1 showed that increase in contaminant volume results in a simultaneous decrease in leached concentration. With the passage of time, at contaminant volume of 225ml, an increase in further contaminant volume resulted in a simultaneous increase in leached concentration.

Figure 3.2 and 3.3 showed that diesel spills with higher contaminant volume will impact more in groundwater following release on Khana soil (Kadafa, 2012). Hence prevention of diesel spill will reduce its impact on environmental aspects (groundwater) and this agrees with the thought of Aniefiok, Thomas, Clement, Ekpedeme and Iniemem (2018).

V. RECOMMENDATION

The following is recommended that Khana Local government in alliance with National Oil Spill Detection Regulation Agency (NOSDRA) should ensure implementation of zero tolerance to diesel spill in all operational oil and gas industries as this 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 determines the effect of contaminant volume on the transport of diesel in Khana soil where most diesel spill occurs.

The best containment technique for cleanup of diesel contaminated soil in Ogoni land would be easily obtainable.

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.