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Influence of Varying Rainfall Intensities on Spilled Diesel Transport in Bori-Ogoni Soil

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ABSTRACT
This research is aimed at investigating the effects of varying rainfall intensities on diesel spill transport in Niger Delta soil. The objectives are to monitor the movement of diesel at given soil depths, different contaminant volumes and rainfall intensities. Diesel spill poses problems to groundwater in Niger Delta which include cancerous and mutagenic effects on citizens of contaminated zones, destruction of aquatic lives; and plants and animals. Response surface method (RSM) was used in generating the experimental design. XLSAT software was used to develop the retention model. 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 result 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 and further increase in rainfall intensity will lead to more increase in the washouts. Rainfall intensity had the highest standardization coefficient of 0.8. Hence, spills on soil are likely to have more groundwater contamination impacts during period of high rainfall intensity. The Ministry of Environment should ensure immediate implementation of zero tolerance to diesel spill in all operational oil industries and diesel fuel users as this will help in fulfillment of ISO 14001:2015 requirements.

KEYWORD: Rainfall intensity, washout, gas chromatography, sieve analysis, unsaturated soil.

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I. INTRODUCTION

Niger Delta, located down the Southern divide of Nigeria, comprises mainly of states trans-divided by the river Niger and its tributaries (Collins, 2018). Bori is located at Latitude 4°40′34″N and Longitude 7°21′54″E. Its elevation above sea level is 18m (59 ft). Bori is in Khana Local Government Area of Rivers State in the Niger Delta zone of Nigeria (Ukaji and Solomon, 2014). Niger Delta region usually experiences high amount of rainfall compared to other regions in Nigeria. Climate change due to global warming has vehemently increased the rate of rainfall in world. This increase could increase the chances of oil spill groundwater contamination. Niger Delta is an environmentally sensitive region because the soil geological formation is very poor and could increase the chances of extreme oil spill ground water contamination (Akpotor., 2019). Citizens of the region are majorly famers and fisher men (Yakubu, 2017). UNEP report, 2011 showed that the huge population of native indigenes and immigrant settlers in the land is due to the establishment of Rivers State Polytechnic, Bori , and also oil industries.

Diesel spill contamination in Bori is a serious threat to livelihood owing to the fact that the soil geological formation is very poor (Kola-Olusanya and Mekuleyi, 2018). Sources of drinking water are surface water and unconfined aquifer. It naturally has quicker groundwater recharge and hydrological circle. Increased industrial activities and transportation of diesel fuel for the generation of electricity in the polytechnic, business centres, and private and public houses equally increase the chances of diesel spill in Khana metropolis. Pipeline vandalization and oil theft related to community crises in cause so much spills in Khana farmlands. Humans, plants, animals and aquatic lives are dying in their numbers (Olaifa and Osuagwu, 2017). Therefore, there is need to reclaim the oil spilled land (Fentimana and Zabbey , 2015).

This research is focused on monitoring the transportation of diesel spill in Khana farmlands.

Soil samples were obtained from farmlands, contaminated with diesel and subjected to varying rainfall intensities by simulation. After this was the extraction of diesel spill from the contaminated soil and water was carried out, tested for total petroleum hydrocarbons and analyzed using RSM Excel start program to monitor the influence of rainfall intensity in the retention of diesel in Khana soil. Diesel spill transport is influenced by several factors which includes diesel properties (Priyanka, Bhatia, Jaswinder, and Rashmita, 2015), volume of contaminant (diesel), subsurface flow conditions, time and duration of release, properties of diesel spill contaminated soil (Ugwoha, Nwankwo, and Okoronkwo, 2016), and coefficient of permeability (Kd factor) of the soil (Yang, Yang, Du, and Lei, 2018).

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 done to monitor the influence of rainfall intensity on Khana soil. The experiment setup adopted 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 then driven using 50kg hammer to a 1000mm depth. The auger rig was disassembled to remove the collector undisturbed. Next, the soil collector that served same purpose of a mesocosm was properly inserted in a lysimeter where the calibrated rainfall simulator was installed with its base properly guided with a net to prevent erosion and filter washouts 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 rainfall. 300mm void in the soil collector was kept to prevent overflow of accumulated rainfall simulated water.

The rainfall simulator was calibrated to mimic rainfall at varying intensities of 5mm/h, 7.5mm/hr and 10mm/hr as shown in Plate 1.

After contaminating the entire soil and simulation of rainfall, the washouts were properly collected after 1hr 45 minutes for each experiment. The volume of the washouts were recorded and stored in cold environment at the end of each experiment. The soils were emptied into a flat tray, mixed properly before measuring 500g for gas chromatography test.

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

To extract water from the washout, hexane (C_6H_{14}) was used as the reagent for extraction because it is the first liquid in the hydrocarbon (HC) series and has minimal level of evaporation. Collected contaminated soil samples were properly washed and dried. 50ml of washout and hexane were mixed in a washed bottle, agitated for 30mins, poured into a separating funnel and allowed to stand for 1hr. The hydrocarbon (diesel) was extracted by discarding the water from the mixture in the separating funnel. The extracted hydrocarbon was well arranged and labeled in a tube for identification as shown in plate 1. The same procedure was used to extract hydrocarbon form the soil. The soil samples were first dried to remove the moisture content. 5g of the dried contaminated soil was weighed using the analytical weighing balance. 50ml of extraction solvent (hexane) was mixed with the contaminated soil, agitated for 30mins before separation with filter papers. The process of filtration was done quickly to avoid evaporation of the solution. The hydrocarbon was properly discarded from the soil particles well arranged and labeled in a tube for identification as shown in Plate 1.

2.4 Gas Chromatography

1µl of concentrated petroleum hydrocarbon sample extract was injected through a rubber septum into the column of a gas chromatography by means of hypodermic syringe. The various fractions of the aliphatic compounds (C_8-C_{40}) were automatically detected as they emerged 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 observations. It was used to optimize the output variables which in this case were the 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 was constant, it was neglected. Nine (9) observations/experimental runs were generated as presented in Table 3.1 below.

2.7 Model Assumptions

The following assumptions were made in development of the model:

i. The soil was sourced from a typical Khana farmland.
ii. The rainfall intensity was simulated to vary between 5mm/hr, 7.5mm/hr and 10mm/hr.
iii. The soil depth is 1000mm.
iv. The diesel contaminant volumes vary from 50ml to 400ml.

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 3.1. 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. Table 3.1 showed the results of leached diesel concentration through a constant soil depth of 1000mm at varying rainfall intensities and contaminant concentrations.

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

3.2 Standardization Coefficient of Leached Concentration Diesel

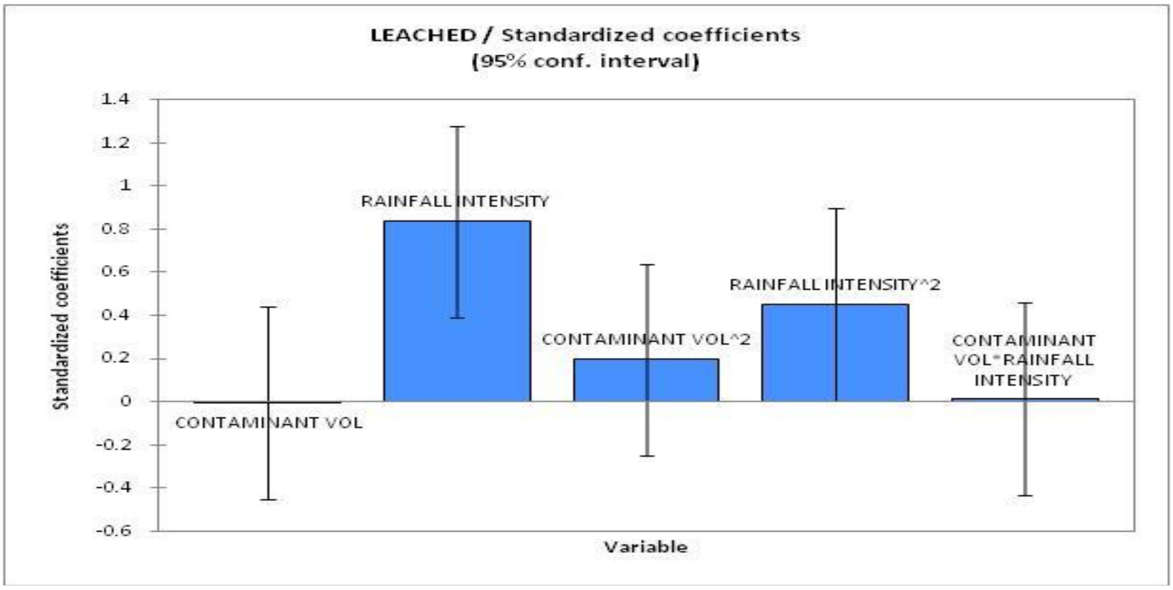

Figure 3.1.Wash out / Standardized coefficients

Discussion of the result in figure 3.1

i. Generally, the bar charts in figure 3.1 showed that the leached concentration of the diesel components were influenced more by the highest rainfall intensity. Hence diesel spills on soil are likely to have more groundwater contamination impacts during period of high rainfall intensity (Olaifa and Osuagwu, 2017).

ii. Since the rainfall coefficient is the highest at 0.82, it means an increase in rainfall intensity will greatly increase the rate of leached concentration. Hence should be considered as more important standardized coefficient compared to other coefficient presented when developing the model.

iii. The leached concentration of diesel varies with different rainfall intensities. It increases with increased rainfall intensity

3.3 Relationship between Leached Concentration and Contaminant Volume

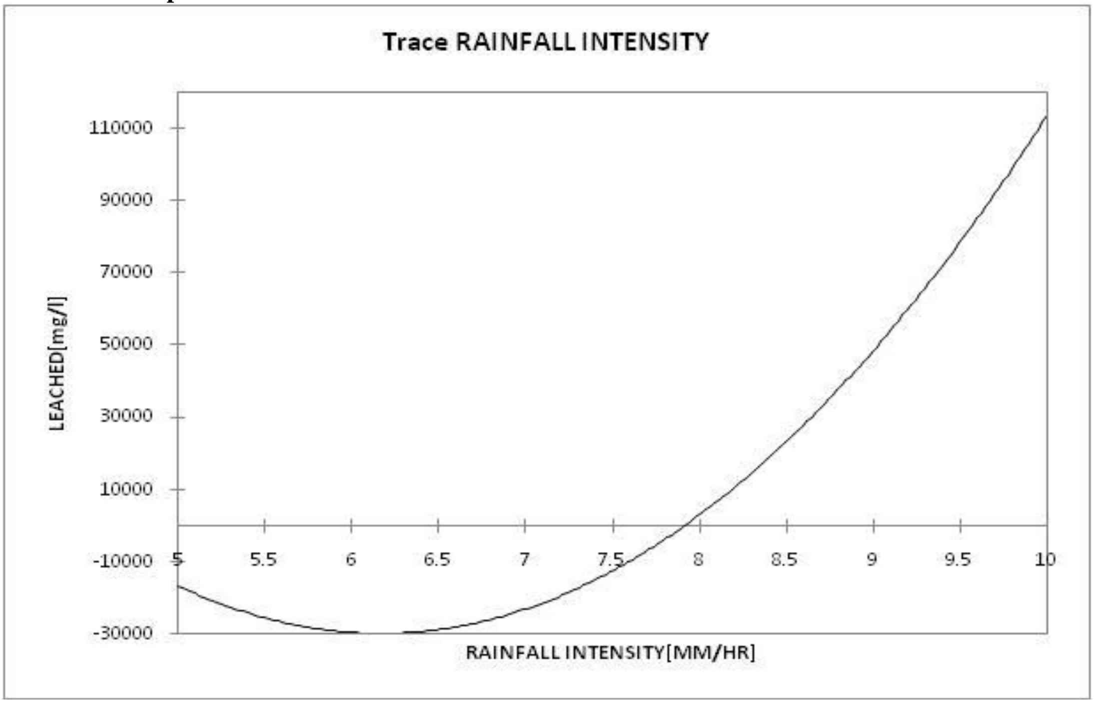

Figure 3.2.Leached Concentration through varying rainfall intensites

Discussion of the result in figure 3.2

i. Figure 3.2 showed an initial decrease in the leached concentration from -2000mg/l to -3000mg/l when rainfall increased from 5mm/hr to 6.2mm/hr. The decrease was caused by the high rate of instauration of the soil, permeability and infiltration constants.

ii. The result 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.

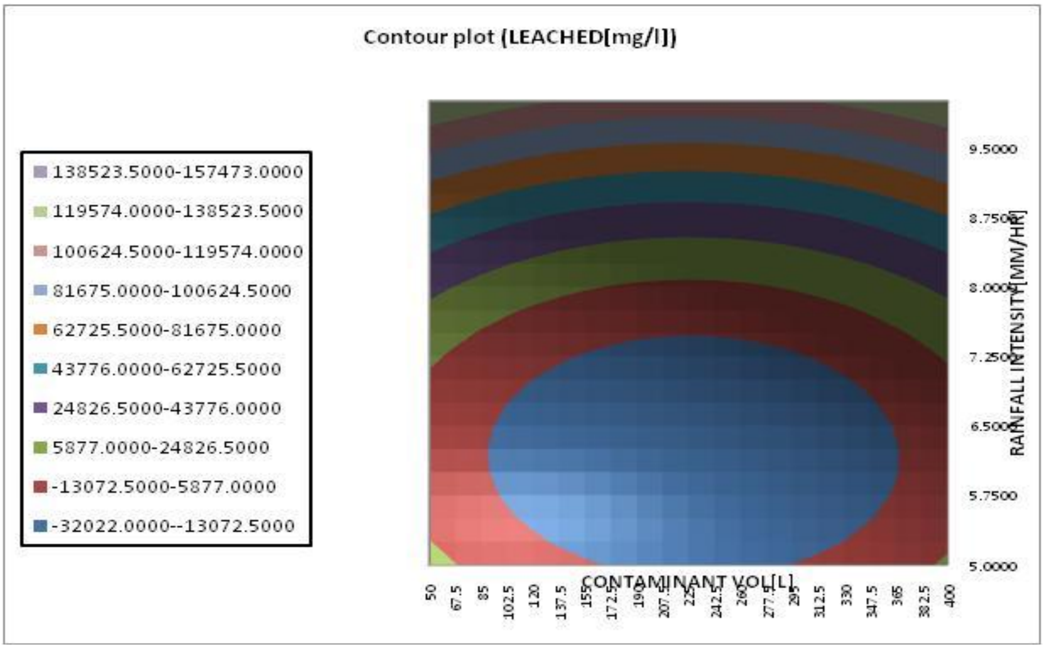

Figure 3.3.Contour plot (Wash out [mg/l])

Discussion of the result in figure 3.3

i. Figure 3.3 showed the relationship between contaminant volume and rainfall intensity.

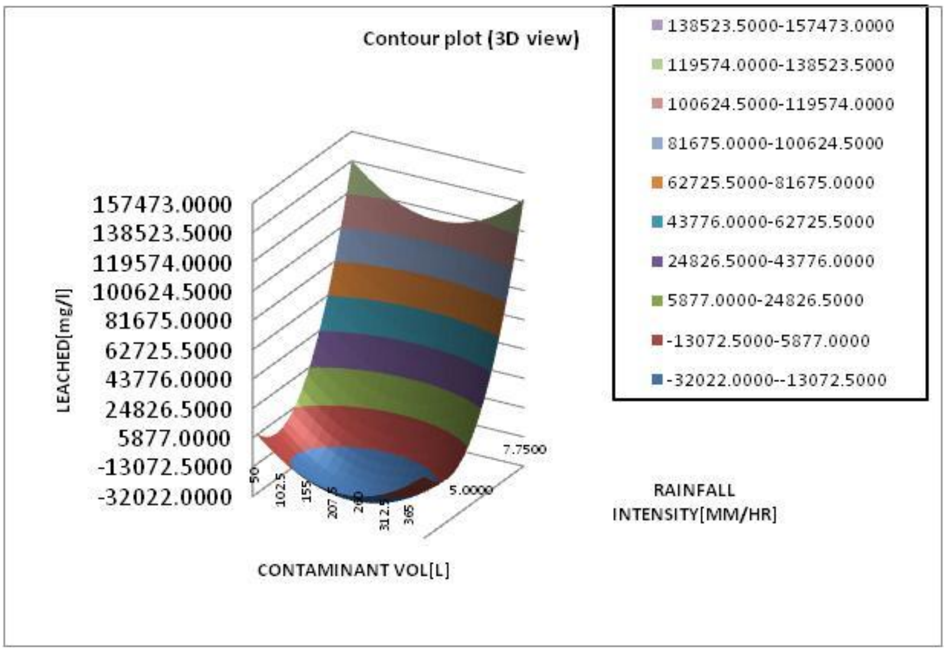

Figure 3.4. Contour Plot (3D view)

Discussion of the result in figure 3.4

i. Figure 3.4. is a 3D view of the developed model that showed the relationship between rainfall intensity and leached concentration.

ii. The highest leached concentration of 110,000mg/l was attained at the highest rainfall intensity of 10mm/hr. This means that increased rainfall intensity will impact more on groundwater.

IV. CONCLUSION

The standardization coefficient of leached diesel chart presented in figure 3.1 showed that diesel spills on soil are likely to have more groundwater contamination impacts during period of high rainfall intensity (Olaifa and Osuagwu, 2017) as evidenced with the highest coefficient factor of 0.82.

Figure 3.1 equally 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 and a further increase in rainfall intensity will lead to more increase in the washouts. Hence increased rainfall intensity will impact more on groundwater quality.

Figure 3.3 and 3.4 also account for zero tolerance to diesel spill as increase in rainfall intensity vehemently increases the chances of groundwater contamination.

V. RECOMMENDATION

It is recommended that Federal Ministry of Environment in alliance with National Oil Spill Detection Regulation Agency (NOSDRA) should implement zero tolerance to diesel policy all over Khana by all operational industries and users of diesel as this will help to save lives of citizens and fulfill the requirements of ISO 14001:2015 standards.

VI. CONTRIBUTION TO KNOWLEDGE

i. The research will help in determining best containment technique for cleanup of diesel contaminated soil in Khana.
ii. The research will help in the implementation of environmental management system as per clause 5, 6,7, 8,9 and 10 of ISO14001:2015.

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PLATES

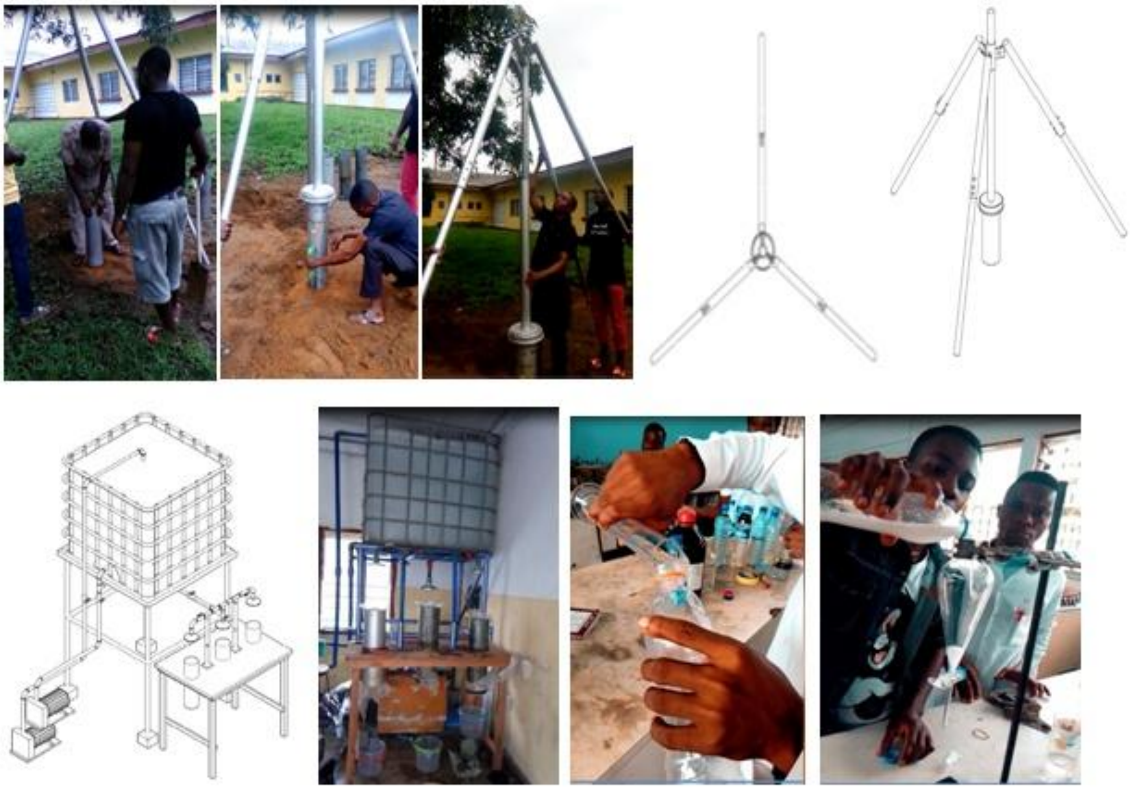

Plate 1. Installation of the fabricated auger rig undisturbed soil collector before soil collection.