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RESEARCH ARTICLE OPEN ACCESS

Diesel Spill Transportation Modeling of Niger Delta Soil

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ABSTRACT

This research is aimed at modeling the transportation of diesel spill in Niger Delta soil. Water-oil fluid interactions in soil possess problems which include: contamination of groundwater, destruction of plants and animals, acute and chronic infection of humans living in the contaminated zones, destruction of aquatic lives and ecosystem; and extinction of plants and animals. 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 for leached and retained 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. The results showed variations in the transportation of diesel with the independent and constant variables. The models were used to fit the transportation of diesel in silty clay soil after accidental release with correlation coefficient of 0.9407 and 0.9501 for the leached and the retained respectively. 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.

KEYWORDS: Transportation model, diesel fuel, gas chromatography, 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″E. Its elevation above sea level is 18m (59ft). Bori is in Khana Local Government Area of Rivers State in the Niger Delta Zone of Nigeria (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), showed that huge population of native indigences and immigrant settlers 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 (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 spells doom and catastrophe (Pegg and Zabbey ,2013). 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 sea foods have gone into extinctions (Kadafa, 2012). Hence there is need to reclaim the oil spilled land (Fentimana and Zabbey , 2015). All of these account for the reasons why Bori is the 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.

Total Petroleum Hydrocarbon (TPH) test was done to obtain the amount of pollution in the soil at 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 the soil samples after the rainfall simulation were noted as retained sample. The soil was thoroughly mixed together before a portion was collected for TPH test. Models of the transportation and retention of diesel following its release on ground surface were done using RSM software.

The diesel 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 .

$$C_8H_{18} + 12.5\,O_2 \rightarrow 8CO_2 + 9H_2O \quad 1.$$

The air produced is 21% oxygen and 79% nitrogen. The soil used in this study was obtained from Ogoni land, precisely from Bori, the capital of Khana Local Government Area of Rivers State. It was a silty clay soil precisely collected from the Engineering Campus of Kenule Beeson Saro Wiwa Polytechnic. Clay soil is the common type of soil found in Bori region. The soil was excavated undisturbed using an auger rig undisturbed soil collector.

Several factors such as properties of the diesel (Priyanka, Bhatia, Jaswinder, Rashmita (2015), volume of the diesel, subsurface flow conditions, time and duration of release, 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 work of Yang, Yang, Duand Lei (2018) showed that a higher Kd is obtained when the adsorption coefficient (Kd) according to the soil properties especially smaller aggregates is determined.

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 model the transport and the retention of petroleum products in sandy soil. The experiment 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. Next, the soil collector that served same purpose of a mesocosm was properly inserted in an opening on a lysimeter with a mesocosm where the calibrated rainfall simulator was installed. Moreso, water was pumped into a 1000liter thank that was used to mimic rainfall at varying intensities of 5mm/h, 7.5mm/hr and 10mm/hr. 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. Washouts were properly collected after 1hr 45 minutes for a particular 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. The soils were emptied into a flat tray, mixed properly before measuring 500g and stored in a cold environment with a 1 liter plastic container shielding from any form of radiations incident on it. The samples were conveyed to Rivers State University for petroleum hydrocarbon test. The diesel was carefully extracted from the well labeled soil samples using hexane as shown in Plate 1. The washouts and the soils were properly mixed with hexane in the ratio of 1:10 and 1:50 respectively. The mixture was properly agitated in a sealed container and poured into 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 lesser density. The extracted diesel was then injected into a gas chromatography to determine its total petroleum hydrocarbon.

2.2 Analysis of Sample

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

2.3 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 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 (9) observations/experimental runs were generated as presented in Table 3.1.

2.4 Model Assumptions

The following assumptions were made in the development of the model.

i. The soil is a silty clay soil common at Bori-Ogoni land.
ii. The rainfall intensity is simulated to vary from 5mm/hr to 7.5mm/hr to10mm/hr.
iii. The soil depth is 1000mm.
iv. The diesel contaminant volume varies from 50ml to 225ml to 400ml.

III. RESULTS AND DISCUSSION

The results and discussions are presented below.

3.1 Leached Concentration of Total Petroleum Hydrocarbons (TPHs) from Collected Water Sample

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 1

i. 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 simulations increase in leached concentration from 633.91mg/l to 739.23mg/l.
ii. 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.
iii. Table 1 presents the results of leached concentration through a constant soil depth of 1000mm at varying rainfall intensities and contaminant concentrations.
iv. Result 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 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 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.

3.2 Standardization Coefficient of Leached Concentration Diesel

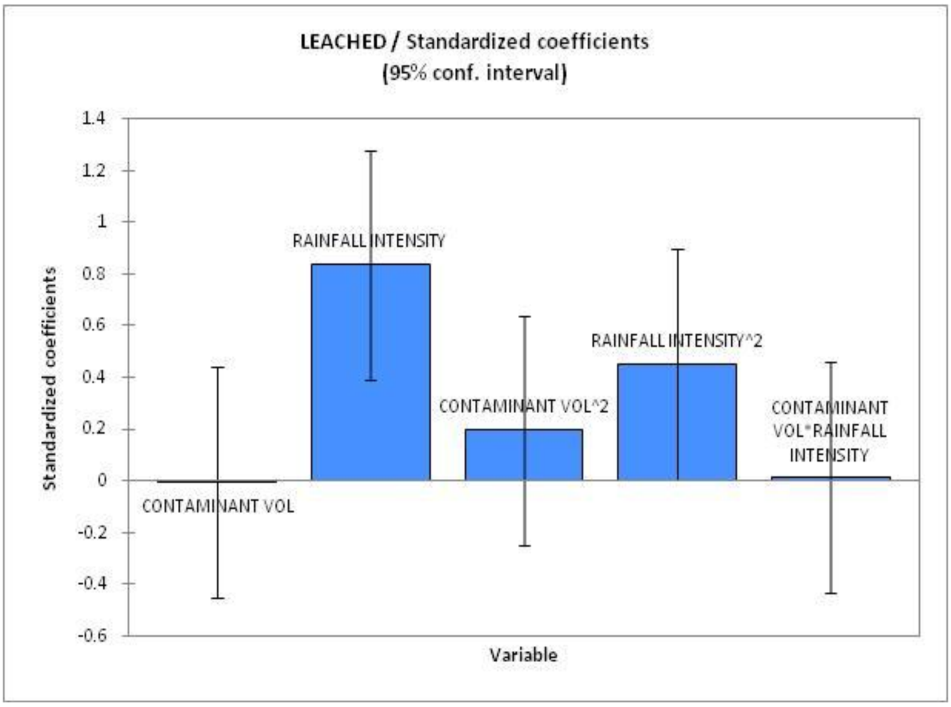

Figure 1.Wash out / Standardized coefficients

Discussion of the result in figure 1

i. Figure 1. Showed a higher standardized coefficient of 0.82 of rainfall intensity, hence it would be considered as a more important standardized coefficient compared to other coefficients presented when developing the model.

ii. Since the rainfall coefficient is 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^2and rainfall intensity^2 sequel to its 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 figure1 shows that the leached concentrations of the diesel components were affected more by the highest rainfall intensity.

vii. Therefore, 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).

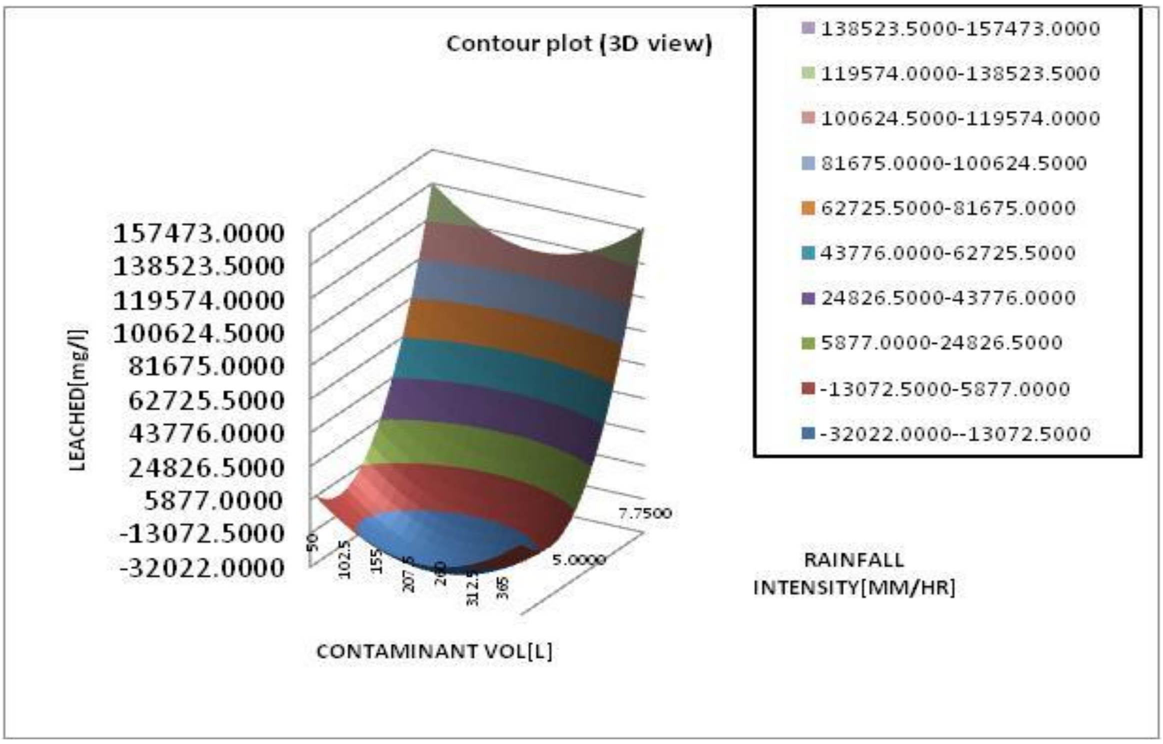

Figure 2.Contour plot (3D view)

Discussion of the result in figure 2

i. It showed a 3D view of the developed model.

ii. Figure 2. showed the relationship between contaminant volume and leached concentration.

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

3.3 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.

$$LC = -12458-432.07000* Cv +64936* RI +26287* Cv ^{\wedge}2+60880* RI ^{\wedge}2+1136* Cv * RI \qquad 2$$

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 which had 92.24833.

ii. Therefore, 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 which had 92.24833. This implies that spills with higher contaminant volume will impact more in groundwater when ever diesel spill occurs (Bautista, and Rahman, 2016) (Sarbatly, Kamin and Krishnaiah, 2016).

iv. 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).

3.5 Model Validation

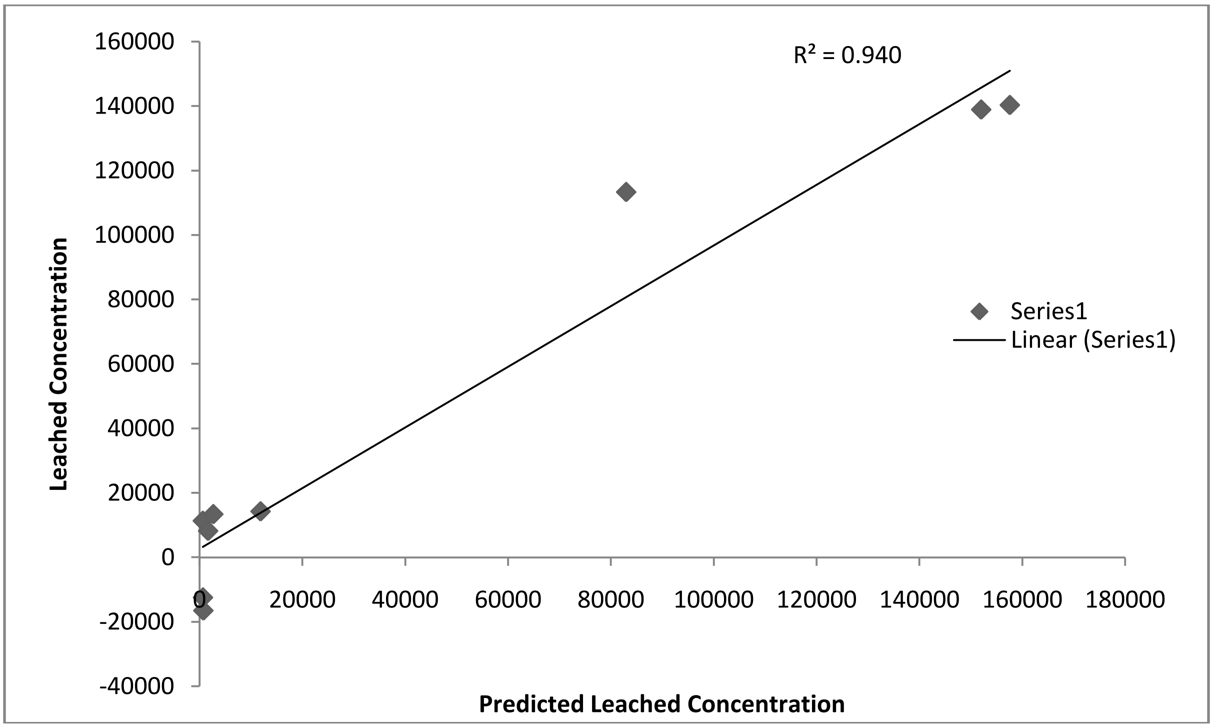

Figure 3. Relationship between the actual and predicted retained concentration

Discussion of the result in figure.3

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 trend line giving a line of best fit with a correlation coefficient of 0.9407 .
iv. This implies that the model can adequately predict the leached concentration of diesel in the unsaturated zone following release (Ugwoha et al., 2016).
v. This implies that an increase in rainfall intensity will aid the impact of diesel on groundwater contamination which agrees with the works of Brakorenko, and Korotchenko (2016).

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.

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. More concern should be given to rainfall intensity, contaminant volume^2and rainfall intensity^2 sequel to its higher standardized coefficient of 0.82, 0.2 and 0.6 respectively as shown in Figure1.

Generally, the bar charts in figure 1 show that the leached concentration of the diesel components were affected 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 and contaminant volume (Olaifa and Osuagwu, 2017).

The leached concentration model developed 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 following release 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 this agrees with the thoughts 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 trend line giving a line of best fit with a correlation coefficient of 0.9407. This implies that the model can adequately predict the leached concentration of diesel in the unsaturated zone following release (Ugwoha et al., 2016).

V. RECOMMENDATION

It is recommend that Khana Local Government Area 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 Niger Delta where most oil spills occur. The best containment technique for cleanup of diesel contaminated soil in Ogoni land is 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.

REFERENCES

[1]. 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

[2]. 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.

[3]. 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

[4]. 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.

[5]. 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).

[6]. 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

[7]. 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.

[8]. 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*2017*31* (4), 3708-3716.DOI: 10.1021/acs.energyfuels.6b03297.

[9]. 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

[10]. 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).

[11]. 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.

[12]. 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.

[13]. 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, Volume 212, 2018, Pages 1054-1061 https://doi.org/10.1016/j.proeng.2018.01.136

[14]. 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*, Volume 48, Issue 3, July 2013, Pages 391–405, https://doi.org/10.1093/cdj/bst021

https://academic.oup.com/cdj/article-abstract/48/3/391/310555

[15]. 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.

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

[17]. 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.

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

[19]. 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, November, 2014 https://www.researchgate.net/publication/311799866

[20]. 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

[21]. 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) pp 1-99 https://www.mdpi.com/2076-3298/4/2/28/pdf

[23]. 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.