

**Analysis of Soil Quality in a Deltaic Hydrocarbon Polluted Environment Niger Delta  
Nigeria**

**Abstract**

*The study was set to ascertain the damage done by oil spill on the soils of Ogbia area in Bayelsa State, Niger Delta, Nigeria. The study adopted the experimental research design which entailed the use of field measurements and a control site. Three communities which are Elebele, Imiringi and Otusega where used for the study. At each of the sample locations three random spots was augered at two depth-levels (Top Sample (T), 0 – 15cm; Bottom Sample (B), 15- 30 cm), with the aid of an auger to collect the samples for laboratory analysis. The parameters of interest to the study are TPH, THC, Organic Matter, THF, THB, P<sup>H</sup>, sand, silt clay and soil texture and these were analysed using standard techniques as recommended by DPR (EGASPIN, 2002). The study revealed that there is a noticeable effect of oil exploitation activities on soil quality within the study area, In the case of THC, the result revealed that the level of THC in the sampled communities was higher than that of the non spill site, hence the presence of hydrocarbon which have caused the pollution of the soil. Organic matter content of the soil also reveals that the non polluted site has more organic content than the sampled communities. The study revealed that there is a statistically significant difference in soil quality of the selected communities and that of the non spilled site. The study therefore recommended a complete and total remediation of the soils in the area, as this will enhance the soil for increased food production.*

**Keywords: soil, hydrocarbon, polluted, deltaic, environment**

**Introduction**

Over the years there have been a rising demand for oil and the dependence on oil revenue has greatly increased. This increase has brought an increase in the economic development of Nigeria, but the situation has led to an increase in environmental, degradation, pollution and contamination of the soils in the Niger Delta. This has arisen from the breakdown of oil pipelines and wells as well as petroleum distribution processes. Oil spills on land have brought about a reduction in soil fertility which has affected food production (Sparrow & Sparrow, 1988; Racine, 1993).

While the benefit of the oil industry is not in doubt, it's explorative, developmental and production processes generates a lot of waste amongst which are of "drilling cuttings, drilling

37 fluids, produced water, sludge, completion and work over fluids, trace metals, heat waste and  
38 oxides of carbon, Sulphur and nitrogen” (Nwilo & Badejo, 2005). Fluids and cuttings arising  
39 from oil drilling are the largest waste sources during exploration. It is speculated that at least two  
40 barrels of fluids and cuttings are generated per foot of a typical well drilled (Nwilo & Badejo,  
41 2005).

42 Several studies have revealed that oil pollution affects the quality of soils; in the study conducted  
43 by Bada and Olarinre (2012), revealed that leaves had more heavy metal content in plants than  
44 stems and roots.

45 Furthermore, Oyem and Oyem (2013), in Ugborodo community on oil spillage impacts on the  
46 soil physico-chemical properties. Arising from oil spillage, it was observed that among the four  
47 sampled communities parameters measured indicated high amount of hydrocarbon, hence a turn  
48 out low fertility, which will bring about low food production and its attendant effects on the  
49 sources of livelihood available to the people.

50 Ugboma, (2014) in a separate study on showed that soil physical and chemical characteristics  
51 was affected by oil spill which resulted in soil fertility decrease and crop productivity decline as  
52 well. This therefore provides evidence that oil spill affects soil quality which in turn affects the  
53 quantity of food production in an area.

54 The record of oil exploitation activities can be likened to the record of oil poison. This is  
55 because as oil exploration and exploitation commenced the next that happened “almost  
56 immediately was the three major causes of oil pollution namely; the impact of the seismic  
57 survey, gas flaring and oil spills” (Pyagbara, 2007). The consequences of oil exploitation on the  
58 environment with emphasis on the soil quality informed the need for this study.

59 Through a large number of literature research, the harm of oil-polluted soil mainly includes the  
60 following aspects: Firstly, because of the small density, higher viscosity and lower emulsifying  
61 ability of petroleum, it is easy to be absorbed in soil surface, affecting the permeability and  
62 porosity of soil (Wang, 2009; He et al, 1999); petroleum is rich in carbon and a small amount of  
63 nitrogen compounds, so it can change the composition and structure of soil organic matter and  
64 impact the C/N, C/P, salinity, pH, EH and conductivity of soil (Li et al, 2009).

65 The heavy metals (nickel and vanadium) in oil mixtures (Saadat et al, 2014) and high  
66 concentrations of salt in oilfield output water can also damage the soil environment (Efsun et al,  
67 2015). Secondly, microorganisms in natural environment are quite abundant in healthy and clean  
68 soil. In normal situation the microorganisms which can resist the oil pollution stress are not  
69 developed, while in contaminated soil, in order to adapt to this kind of environment, they can  
70 produce certain enzyme system and gradually form a dominant population with symbiotic or  
71 synergy effect (Chiara et al, 2009).

72 A number of studies have shown that the hydrocarbon pollution can change the microbial  
73 population, the composition of the community structure and the enzyme system in soil, given  
74 priority to the inhibitory action (Deng, 2014; Uzoije and Agunwamba et al, 2009). Thirdly, it can  
75 impede the normal growth of crops such as reduce the germination rate and fertility and decline  
76 the resistance to pests and diseases (Xu and Lu, 2010; Zhu, 2010; Shan et al, 2014). In addition,  
77 the oil compounds could react with inorganic nitrogen and phosphorus, limiting the nitrification  
78 and removal of phosphoric acid, so the effective nitrogen and phosphorus in the soil would  
79 decrease and the absorption of crops will be affected (Liao et al, 2015; Pinchin et al, 2013; Shen,  
80 2011).

81 Moreover, the polycyclic aromatic hydrocarbons in petroleum chemicals have carcinogenic,  
82 mutagenic, teratogenic and other toxic effects. It can enter into the bodies of people and animals  
83 through breathing, skin contact and diet, degrading the normal function of livers and kidney etc,  
84 therefore causing great threat to human's health. At last, the oil pollutants in the soil not only  
85 impact the pedosphere, but also the atmosphere and water sphere.

### 86 *The Study Area*

87 The area of study are Imiringi, Otuasega and Elebele communities which are located within the  
88 Kolo Creek, which is located  $4^{\circ}.47'0''\text{N} - 6^{\circ}.25'0''\text{E}$  within the lower Niger Delta. (See fig 1.1).

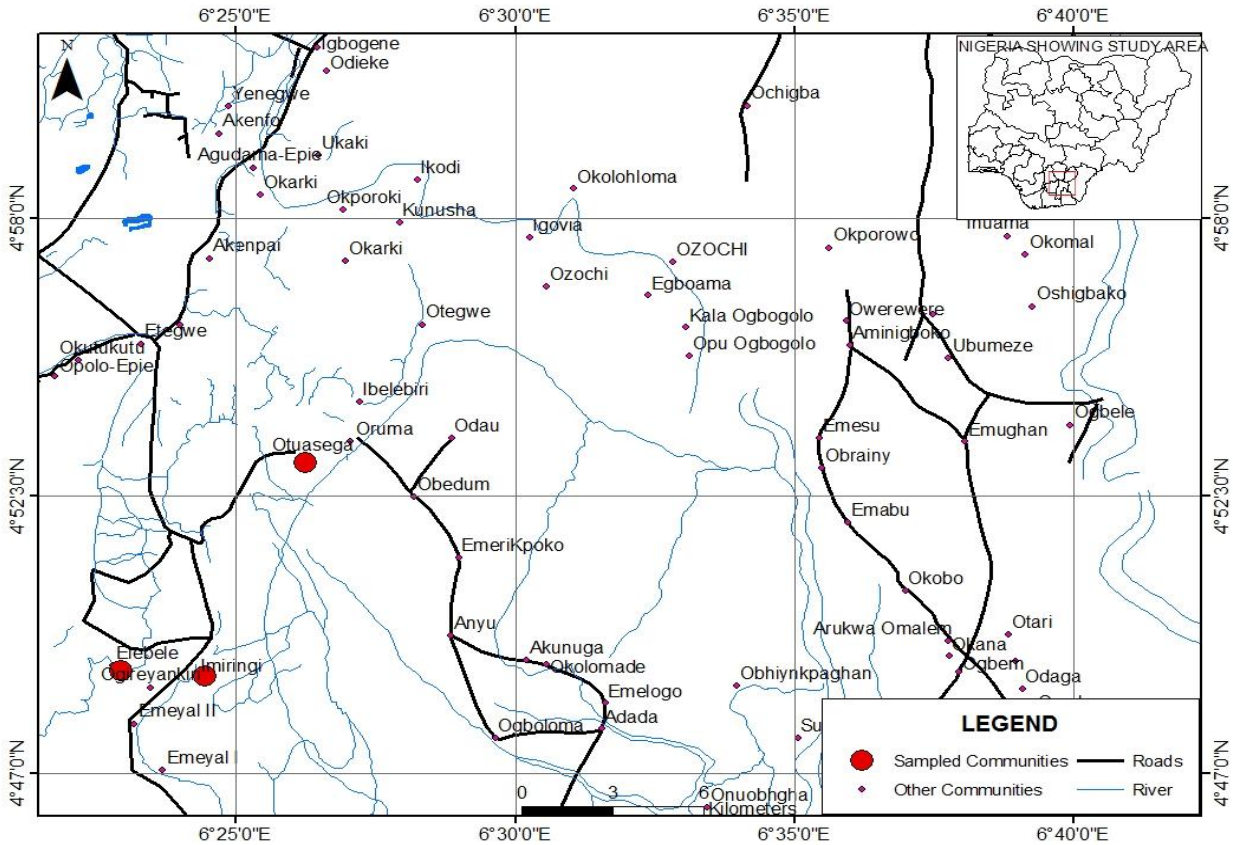
89 Ogbia is one amongst other local government areas in Bayelsa State, with the Head Quarters  
90 situated in the town called Ogbia which is located on the South of the area within Latitude  
91  $4^{\circ}45'00''\text{N} 6^{\circ}39'00''\text{E}$ . It covers a total area of  $695 \text{ km}^2$ . Kolo Creek oil and gas field as called by  
92 SPDC is located in Imiringi town. The name Kolo creek as called by SPDC, and is "named after  
93 Kolo Creek in Ogbia Local Government Area of Bayelsa State. The area is located about 10km

94 North West of Yenagoa, which is the capital city of Bayelsa State. It is characterized by tropical  
95 rain forest and fresh water swamps that are usually flooded in the raining season”.

### 96 *Materials and Method*

97 The study was conducted in the Kolo Creek area as called by Shell Development Company of  
98 Nigeria (SPDC) which is basically made up of three communities in Ogbia; there are Imiringi,  
99 Otuasega having and Elebele communities which were selected for the study because of the  
100 presence of oil wells in the communities. The study adopted the use of the experimental research  
101 design which enabled the researchers achieve the purpose of the study.

102 Since the interest of the study is on soil quality, soil samples were collected using a systematic  
103 sampling pattern (Tel and Hagarty, 1984). At each of the sample locations three random spots  
104 was augered at two depth-levels (Top Sample (T), 0 – 15cm; Bottom Sample (B), 15- 30 cm),  
105 with the aid of an auger. Also, at each of the sample locations and soil depth levels (T or B), the  
106 soil samples were bulked together to give a composite sample. The soil samples from different  
107 sample locations and soil depth levels were on each occasion collected in polythene bags and  
108 labeled accordingly and sent to the laboratory for analysis. Two hypotheses was also put forth to  
109 guide this study.



110

111 **Fig 1: Ogbia Area showing sampled communities**

112

113 ***Analytical Procedure for Soil Quality Analysis***

114 ***Total Heterotrophic Bacteria***

115 1gram of water sample is weighed into 9ml sterile diluents (0.85% NaCl) under aseptic  
 116 condition. It is shaken vigorously to homogenize and serially diluted. Then 0.1ml aliquot of the  
 117 inoculums is collected using a sterile pipette, inoculated on Nutrient Agar (NA) surface. The  
 118 inoculums are spread evenly with sterile hockey stick (Bent rod). Plates are incubated at 37<sup>0</sup>C for  
 119 24 hours. Thereafter, colonies are counted to obtain colony forming unit (cfu) value per ml of  
 120 water sample. Distinct colonies are picked and streaked or subculture on freshly prepared  
 121 Nutrient Agar medium to obtain pure culture after 24 hours incubation at 37<sup>0</sup>C. The pure culture  
 122 is gram stained for microscopic examination. It is also used to carry out biochemical tests for  
 123 characterization and identification of the isolates.

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125

126 **Total Petroleum Hydrocarbon**

127 This analysis shall be done using gas chromatography/flame ionization detector method.  
128 Methods 3580A and 3550C describe procedure used for extracting non-volatile and semi volatile  
129 organic compounds from solids such as soils, sludge and wastes, while method 8000 describes  
130 the determinative steps employed in the GC/FID of sample extracts obtained using the methods  
131 described above.

132  
133 **Soil pH Determination**

134 The ph of soil was done with the aid of a pH meter.  
135

136 **Results**

137 The results of the laboratory analysis of the soil samples collected from the selected communities  
138 are presented in the table below.

139 **Table 1: Result of Physico-Chemical/Microbiological Analysis of Soil**

<b>Parameters</b>	<b>Imiringi</b>	<b>Elebele</b>	<b>Otuasega</b>
TPH(mg/kg)	178.77	1,732.50	132.51
THC(mg/kg)	277.2	2246.0	223.7
Organic matter (%)	7.440	14.890	11.280
THF(cfu/g)x10 <sup>3</sup>	1.2	0.2	0.2
THB(cfu/g)x10 <sup>3</sup>	3.2	1.0	1.2
p <sup>H</sup>	6.30	6.50	5.30
Sand (%)	11.2	12.7	11.9
Silt (%)	31.6	33.4	32.8
Clay (%)	57.2	53.9	55.3
PSD/Texture	Silty clay	Silty clay	Silty clay

140 Source: Researchers field work (2015)

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145 **Table 2: Comparism of soil quality Parameters of polluted sites with Non polluted soil.**

Parameters	Imiringi	Elebele	Otuasega	Non polluted site
TPH(mg/kg)	178.77	1,732.50	132.51	20.18
THC(mg/kg)	277.2	2246.0	223.7	36.0
Organic matter (%)	7.440	14.890	11.280	18.20
THF(cfu/g)x10 <sup>3</sup>	1.2	0.2	0.2	0.5
THB(cfu/g)x10 <sup>3</sup>	3.2	1.0	1.2	2.2
p <sup>H</sup>	6.30	6.50	5.30	7.10
Sand (%)	11.2	12.7	11.9	13.8
Silt (%)	31.6	33.4	32.8	35.2
Clay (%)	57.2	53.9	55.3	51
PSD/Texture	Silty clay	Silty clay	Silty clay	Silty clay

146 **Source Researchers field work (2018)**

147 **Discussions**

148 As seen in table 1, Total Petroleum Hydrocarbon in soils of the selected communities ranges  
 149 between 132.51 and 1,732.50, with Otuasega community accounting for the lowest which is  
 150 132.51mg/kg and Elebele community accounting for 1,732.50mg/kg which is the highest,  
 151 although the result shows that total petroleum hydrocarbon value differs significantly from one  
 152 location to another.

153 Total Hydrocarbon Content in soils of the selected communities ranges between 223.7mg/kg and  
 154 2246.0mg/kg, with Otuasega community accounting for the lowest which is 223.7mg/kg and  
 155 Elebele community accounting for 2246mg/kg which is the highest; although the result shows  
 156 that total hydrocarbon content value in soils differs significantly from one location to another.

157 Organic matter in soils of the selected communities ranges between 7.440 and 14.890, with  
 158 Elebele community accounting for the highest, with an organic content value of 14.890. This was  
 159 followed by Otuasega community with an organic content value of 11.280 and Imiringi  
 160 community with an organic content value of 7.440.

161 Total Heterotrophic Fungi in soils of the selected communities ranges between 0.2 and 1.2, with  
 162 Imiringi community accounting for the highest, with a THF value of 1.2. The two other sampled  
 163 community's Otuasega and Elebele had the same THF value of 0.2 each.

164 Total Heterotrophic Bacteria in soils of the selected communities ranges between 1.0 and 3.2,  
165 with Imiringi community accounting for the highest, with a THB value of 3.2. This was followed  
166 by Otuasega community with a THB value of 1.2 and Elebele community with a THB value of  
167 1.2.

168 pH in soils of the selected communities ranges between 5.30 and 6.50, with Elebele community  
169 accounting for the highest, with a pH value of 6.50. This was followed by Imiringi community  
170 with a pH value of 6.30 and Imiringi community with a pH value of 5.30.

171 Sand level in soils of the selected communities ranges between 11.2% and 12.7% with Elebele  
172 community accounting for the highest, with sand % value of 12.7%. This was followed by  
173 Otuasega community with sand % value of 11.9% and Imiringi community with sand % value of  
174 11.2%. Silt as observed to range between 31.6 and 33.4. The highest was recorded in Elebele with  
175 a percentage value of 33.4% silt; Otuasega had 32.8% silt and Imiringi 31.6% silt.

176 Clay ranged between 53.9 and 57.2 with the highest percentage value of 57.2% recorded in  
177 Imiringi. This was followed by Otuasega with clay percentage value of 55.3% and Elebele with a  
178 clay percentage value of 53.9%. The texture of the soil as shown revealed that the three  
179 community soils are silty clay soil.

180 Table 2 revealed that total petroleum hydrocarbon level in the three sampled communities is  
181 above that of the non polluted site with Elebele community having more concentration of total  
182 petroleum hydrocarbon than the other communities. The result here shows that there is a  
183 noticeable effect of oil exploitation activities of soil quality within the study area.

184 In the case of THC, the result revealed that the level of THC in the sampled communities was  
185 higher than that of the non spill site, hence the presence of hydrocarbon which have caused the  
186 pollution of the soil.

187 The organic matter content of the soil also reveals that the non polluted site has more organic  
188 content than the selected communities. This implies that the presence of oil in the soil due to  
189 pollution has affected the organic content of the soil hence bringing a reduction in its amount  
190 when compared with the non polluted site.

191



192 *Hypothesis Testing*

193 *Table 3: Chi-Square analysis for difference in soil quality between Imiringi (polluted site) and*  
 194 *non polluted site*

Observed	Expected	O-E	(O-E) <sup>2</sup>	$\frac{(O-E)^2}{E}$
178.77	20.18	158.9	25150.79	1246.3
277.2	36.0	241.2	58177.4	1616.0
7.440	18.20	-10.76	115.78	6.36
1.2	0.5	0.7	0.49	0.98
3.2	2.2	1	1	0.45
6.30	7.10	-0.8	0.64	0.090
11.2	13.8	-2.6	45.69	3.31
31.6	35.2	-3.6	12.96	0.368
57.2	51	8.2	67.24	1.32
				<b>X<sup>2</sup> = 2875.12</b>

195  $df = (9-1) (2-1)$

196  $(9-1) (2-1)$

197  $8 \times 1 = 8$

198 Therefore we conclude that X<sup>2</sup> calculated value is 2875.12 while the critical value at 10 degree  
 199 of freedom and 95% significant level is 15.51.

200 The calculated X<sup>2</sup> calculated value 2875.12 is greater than the critical value of 15.51 we therefore  
 201 reject the null hypothesis which states that there is no statistically significant difference in soil  
 202 quality of Imiringi and that of the non polluted site and accept the alternate hypothesis which  
 203 states that there is a statistically significant difference in soil quality in Imiringi and that of the  
 204 non polluted site.

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209 *Table 4:Chi-Square analysis for difference in soil quality between Elebele (polluted site) and*  
 210 *non polluted site*

Observed	Expected	O-E	(O-E) <sup>2</sup>	$\frac{(O-E)^2}{E}$
1,732.50	20.18	1712.32	2932.01	145.3
2246.0	36.0	2210	4884100	135669.4
14.890	18.20	-3.31	10.96	0.602
0.2	0.5	-0.3	0.09	0.18
1.0	2.2	-1.2	1.44	0.65
6.50	7.10	-0.6	0.36	0.05
12.7	13.8	-1.1	1.21	0.088
33.4	35.2	-1.8	3.24	0.092
53.9	51	2.9	8.41	0.165
				<b>X<sup>2</sup> = 135,816.5</b>

211  $df = (9-1) (2-1)$

212  $(9-1) (2-1)$

213  $8 \times 1 = 8$

214 Therefore we conclude that X<sup>2</sup> calculated value is 135,816.5 while the critical value at 10 degree  
 215 of freedom and 95% significant level is 15.51.

216 The calculated X<sup>2</sup> calculated value 135,816.5 is greater than the critical value of 15.51 we  
 217 therefore reject the null hypothesis which states that there is no statistically significant difference  
 218 in soil quality of Elebele and that of the non polluted site and accept the alternate hypothesis  
 219 which states that there is a statistically significant difference in soil quality in Elebele and that of  
 220 the non polluted site.

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227 *Table 5: Chi-Square analysis for difference in soil quality between Otuasega (polluted site)*  
 228 *and non polluted site*

Observed	Expected	O-E	(O-E) <sup>2</sup>	$\frac{(O-E)^2}{E}$
132.51	20.18	112.33	12618.03	625.3
223.7	36.0	187.7	35231.3	978.65
11.280	18.20	-6.92	47.89	2.63
0.2	0.5	-0.3	0.09	0.18
1.2	2.2	-1	1	0.45
5.30	7.10	-1.8	3.24	0.456
11.9	13.8	-1.9	3.61	0.263
32.8	35.2	-2.4	5.76	0.164
55.3	51	4.3	18.49	0.363
				<b>X<sup>2</sup> = 1608.456</b>

229  $df = (9-1) (2-1)$

230  $(9-1) (2-1)$

231  $8 \times 1 = 8$

232 Therefore we conclude that X<sup>2</sup> calculated value is 1608.456 while the critical value at 10 degree  
 233 of freedom and 95% significant level is 15.51.

234 The calculated X<sup>2</sup> calculated value 1608.456 is greater than the critical value of 15.51 we  
 235 therefore reject the null hypothesis which states that there is no statistically significant difference  
 236 in soil quality of Otuasega and that of the non polluted site and accept the alternate hypothesis  
 237 which states that there is a statistically significant difference in soil quality in Otuasega and that  
 238 of the non polluted site.

239 **Hypothesis Two**

240 The second hypothesis of the study, states that there is no statistically significant variation in the  
 241 extent of soil damage amongst sampled communities in Ogbia.

242 The table below shows the variation in the extent of soil damage amongst sampled communities  
 243 in Ogbia.

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246 **Table 6: One way (ANOVA) for variation in soil quality in sampled communities in Ogbia**

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	948295.4	2	474147.7	1.804708	0.186144	3.402826
Within Groups	6305476	24	262728.2			
Total	7253771	26				

247

248 From the table above, it is revealed that calculated F value for the analysis is 1.804708 while the  
 249 critical value is 3.402826. Since the calculated F value of 1.804708 is less than the critical value  
 250 of 3.402826 at  $F^2_{26}$  degree of freedom, the implication of this is that the null hypothesis  $H_0$  of no  
 251 significant difference is accepted while rejecting the alternate  $H_1$  which states that there is a  
 252 statistically significant variation in the extent of soil damage amongst selected communities.  
 253 Arising from the above it is pertinent to state that the study has revealed that there is no  
 254 statistically significant variation in soil quality of the selected communities.

255

256 **Conclusion**

257 The study also set to ascertain the level of damage done by oil spill on the soils and its spatial  
 258 variation in Ogbia, the study therefore revealed that total petroleum hydrocarbon level in the  
 259 three sampled communities is above that of the non polluted site with Elebele community having  
 260 more concentration of total petroleum hydrocarbon than the other communities. The result here  
 261 shows that there is a noticeable effect of oil exploitation activities on soil quality within the study  
 262 area.

263 In the case of THC, the result revealed that the level of THC in the sampled communities was  
 264 higher than that of the non spill site, hence the presence of hydrocarbon which have caused the  
 265 pollution of the soil.

266 The organic matter content of the soil also reveals that the non polluted site has more organic  
267 content than the sampled communities. This implies that the presence of oil in the soil due to  
268 pollution has affected the organic content of the soil hence bringing a reduction in its amount  
269 when compared with the no polluted site.

270 Statistically, the study revealed that there is a statistically significant difference in soil quality of  
271 the sampled communities and that of the non spilled site, but on specific parameter, it was found  
272 that total petroleum hydrocarbon and total hydrocarbon content were higher in the selected  
273 communities than the non oil spilled site. The study further revealed that;

- 274 1. There is a noticeable effect of oil exploitation activities on soil quality within the study  
275 area.
- 276 2. There is also a noticeable decline in the crop production arising from soil pollution  
277 occasioned by oil exploitation.
- 278 3. There is a clear cut evidence of the state of the soil in the polluted sites as compared to  
279 the non polluted which is an indication of the state of the soil having been ravaged by the  
280 detrimental effect of oil exploratory activities in the area.
- 281 4. Total petroleum hydrocarbon level in the three sampled communities is above that of the  
282 non polluted site with Elebele community having more concentration of total petroleum  
283 hydrocarbon than the other communities.
- 284 5. The study revealed that there is a statistically significant difference in soil quality of the  
285 selected communities and that of the non spilled site

286 On the basis of the above, the study recommended a complete and total remediation of the soils  
287 in the area, as this will enhance the soil for increased food production.

288 ***Informed consent:*** Before the commencement of the research the communities were duly  
289 informed of the research which they obliged and provided a guard to assist the researchers during  
290 the period

291

292 ***Competing interests:*** there are no conflicting interests in this work

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