

Original Research Article

Phytoremediation of Petroleum Products Contaminated Soil

ABSTRACT

This study investigated the impact of petroleum products on the physiochemical properties, heavy metals and THC of soil samples; and their possible phytoremediation. Perforated plastic buckets were filled with 10 kg of sieved virgin topsoil. A mixture of 2 L of spent engine oil, 2 L of kerosene, 2 L of petrol and 2 L of diesel was gradually poured into each bucket and allowed to drain through the soil, once a day for five days, and left to stabilize for a period of 21 days. Fluted pumpkin (*Telforia Occidentalis*) and Okra (*Abelmoschus esculentus*, Cv. *Kirikou*) seeds were planted in buckets and closely monitored for 14 weeks. Soil analysis of the virgin topsoil, contaminated soil and remediated soil was done using standard methods. Tests results showed that the petroleum products significantly ($p \leq 0.05$) altered the physicochemical properties, heavy metals and THC of the soil. From the results, the soil porosity decreased from 35% to 14%; specific gravity decreased from 2.34 to 1.35; the soil pH decreased from 7.05 to 5.34; the THC increased from 0,923 mg/kg to 964.35 mg/kg; copper level increased from 4.892 mg/kg to 7.729 mg/kg; the lead content increased from <0.0001 mg/kg to 1.128 mg/kg; while the iron content increased from 1251.2 mg/kg to 1587.9 mg/kg after the contamination. After the 14 weeks phytoremediation period, *Telfairia occidentalis* was able to degrade the THC in the soil from 964.35 mg/kg to 82.67 mg/kg; while *Abelmoschus esculentus* degraded the THC in the soil from 964.35 mg/kg to 104 mg/kg. Therefore, due to the harmful effects of the petroleum products on agricultural soils, laws banning their indiscriminate disposal of should be enforced.

Keywords: *Abelmoschus esculentus*, *Telfairia occidentalis*, contaminated soils, phytoremediation, THC

1.0 INTRODUCTION

Since Nigeria started crude oil exploration in commercial quantity, it has grown tremendously, replacing agriculture which was Nigeria main source of revenue, before the discovery of crude oil [ref](#). But crude oil exploration had a lot negative impact on the environment, if not well managed [ref](#). It has led to the land, air and water pollution through gas flaring, oil spills, indiscriminate disposal of petroleum products etc [ref](#). The people living in the Niger Delta region of Nigeria, the oil exploration hub, are badly affected by oil exploration activities [ref](#). Their fishing waters and farming lands have become polluted leading to poor catch and crop yield [1].

Petroleum contamination in the environment causes serious problem [ref](#). This is because petroleum hydrocarbons compounds are toxic to all forms of life, and have adverse effect on the soil physical and chemical properties [ref](#). Petroleum is a complex mixture of a wide variety of low and high molecular weight hydrocarbons [ref](#). The mixture contains saturated alkanes, alkanes, alkenes, naphthenes, highly toxic polycyclic aromatic hydrocarbons, and some heavy metals [2,3]. Peng *et al.* [4] reported that the population of living microorganisms was highly dependent on the concentration of petroleum contaminants in soil, as uncontaminated soil favoured high bacteria population more than petroleum contaminated soil. Reduced dry mass accumulation of *Gambaya `albida* and *Dacryodes edulis* plants caused by spent oil contamination had been reported [by](#) [5,6] where they noted that hydrocarbons from oil contaminated soils accumulate in the chloroplast of plant leaves.

Phytoremediation uses plants and their associated microorganisms to recover soil and water bodies contaminated with hydrocarbons and other heavy metals [ref](#). Phytoremediation is more environmentally friendly than most conventional clean-up methods used in the remediation of contaminated soil [7,8]. The main mechanisms of phytoremediation include the following: the direct uptake of contaminants and their subsequent metabolism in plant tissues, transpiration of volatile

57 organic hydrocarbons through the stems and leaves, discharge of exudates that stimulate microbial
58 activity, and the enhancement of mineralization at the root–soil interface [9,10].
59

60 | Phytoremediation of contaminated soils using some plants have been studied [ref.](#) Al-Baldawi *et al.*
61 [10] reported that the average total petroleum hydrocarbon (TPH) concentration detected in *Scirpus*
62 *grossus* ranged between 19.86 to 91.36 mg/kg in the roots, and 16.14 to 223.56 mg/ kg in the leaves.
63 Schnoor [11] reported that phytoremediation is more effective with vigorously growing plants, and
64 have the ability to accumulate large concentration of contaminants in body parts (roots, stems and
65 leaves). The ability of given crop to degrade crude oil content in contaminated soil can help to restore
66 polluted soils back for agricultural use [12]. Akpokoje *et al.* [8] demonstrated *Arachis hypogaea* L.,
67 | *Amaranthus hybridus* and *Celosia argentea* planted on soil contaminated with [?](#) were about to
68 degrade the Total Hydrocarbon Content (THC) of petroleum products contaminated soil by about
69 80%. Water hyacinth (*Eichhornia crassipes*) was recorded to significantly remediate petroleum
70 hydrocarbon level in the contaminated soil [13]. According to [14], spent lubricating oil adversely
71 affected soil aeration, soil bulk density and soil water holding capacity. In their report, they stated that
72 the bulk density increased from 1.38 kg/m³ to 3.80 kg/m³, while the water holding capacity decreased
73 from 59 ml to 8 ml [14]. In a study conducted by [15], they reported that fluted pumpkin degraded the
74 Total Petroleum Hydrocarbon (TPH) in a diesel oil contaminated soil from 82.5 mg/kg to 5.8 mg/kg
75 with 18 week experimental period [15].
76

77 Although, reference [15] and other researchers had studied the phytoremediation of diesel
78 contaminated soil using fluted pumpkin (*Telfairia occidentalis*), there is no literature on the
79 phytoremediation of agricultural soil contaminated with mixture of petroleum products using okra and
80 fluted pumpkin plants. It is therefore important to study the ability of okra plant (*Abelmoschus*
81 *esculentus*, cv. *Kirikou*) and fluted pumpkin (*Telfairia occidentalis*) in mitigating the effect of some
82 physicochemical (specific gravity, porosity, bulk density and electrical conductivity) and THC of soil
83 polluted with mixture of petroleum products. Therefore, the objective of this study was to evaluate the
84 role and influence of the Pumpkin (*Telforia Occidentalis*) and Okra (*Abelmoschus esculentus*, Cv.
85 *Kirikou*) within the context of the phytoremediation of petroleum products contaminated soil.
86

87 2.0 MATERIALS AND METHODS

88 2.1 Materials

89 Soil sample

90 The top soil was collected within 6cm depth from a virgin plot at the Delta State Polytechnic research
91 station.
92

93 Petroleum products

94 The spent motor engine oil was purchased from a mechanic workshop located along Ozoro – Oleh
95 road, Delta State, Nigeria; while the petrol, diesel and kerosene were purchased from a filling station
96 located at Oleh, Delta State, Nigeria
97

98 Plant of interest

99 The plants Pumpkin (*Telforia Occidentalis*) and Okra (*Abelmoschus esculentus*, Cv. *Kirikou*) seeds
100 were obtained from the Department of Agricultural and Bio-environmental Engineering Technology,
101 Delta State Polytechnic, Ozoro, Nigeria.
102

103 2.2 Methods

104 Soil sample preparation

105 The dug topsoil was air dried in the laboratory at ambient temperature (23±4°C) for two weeks. After
106 which, it was sieved with 2 mm stainless steel sieve to remove stones and plants roots from it. Plastic
107 buckets were filled with 10 kg of the sieved soil before the contamination with petroleum products.
108 Mixture of petroleum products (2 L of spent engine oil, 2 L of kerosene, 2 L of petrol and 2 L of diesel)
109 was gradually poured into each bucket and allowed to drain through the soil. This procedure was
110 repeated daily for five days, before the contaminated soil in the buckets was left to stabilize for three
111 weeks.
112

113 Soil analysis

114 Soil analysis was done both on the uncontaminated, contaminated (after stabilization period), and the
115 remediated soil sample. The soil bulk density, porosity, specific gravity, pH and Total hydrocarbon
116

117 content (THC) in the soil sample was determined using the standard method recommended by [10,
118 16, 17]. The heavy metals (copper, Iron and Lead) were determined using the atomic absorption
119 spectrophotometer, according to standard methods [18,19].

120

121 **Phytoremediation setup**

122

123 All the buckets filled with contaminated soil were arranged under a shady environment to minimize
124 excessive evapotranspiration and the effects of heavy downpour, during the experimental period.
125 They were arranged in the manner shown in Table 1, for easily data collections.

126

127 Table 1: Phytoremediation set up

Row	Plant
Row 1	<i>Okra</i>
Row 2	<i>Telforia Occidentalis, Fluted pumpkin</i>
Row 3	Control (nothing planted)

128

129

130 Ten seeds (of each plant) were sown into each of the buckets. Three weeks after germination, the
131 seedlings were thinned down to five seedlings per bucket. Before planting, 200 g compost manure
132 (made from green leaves, cattle dungs and poultry droppings) mixed with 100 g of loamy soil was
133 placed on top of all the buckets, to encourage early establishment of the seedlings, as recommended
134 by [8]. All the buckets were moderately watered when necessary to keep the soils moist. Weeding
135 was done by handpicking throughout the experimental period, while systemic pesticide was applied
136 when necessary. Disease symptoms were not observed; therefore, fungicide was not used during the
137 experimental period.

138

139 At the end of the experimental period, random soil samples were taken (0-20 cm depth) from the
140 buckets and coded. This depth (0-20 cm depth) is considered the rhizosphere region of the plants.
141 Rhizosphere region is the region of the soil closest to the plant's root which is under the direct
142 influence of the root system [20]. All the soil samples collected were air-dried and sieved with 2 mm
143 sieve before the soil analysis.

144

145 **Statistical analysis**

146 The statistical analysis of data obtained from this study was done by using the Statistical Product and
147 Service Solutions (SPSS) version 20.0 (Chicago, USA). The means were separated using the Duncan
148 method at 95% confidence level ($p < 0.05$). All the tests were carried out in triplicates to minimize
149 experimental errors.

150

151

152 **3.0 RESULTS AND DISCUSSION**

153

154 **Impact of the petroleum products on the soil**

155 The results of the soil analysis presented in Tables 2 and 3 showed that the petroleum products had
156 significant effects on the physicochemical properties and heavy metals level of agricultural soil. As
157 shown in Tables 2, the soil bulk density, and total hydrocarbon content increased significantly (p
158 ≤ 0.05) after the petroleum products contamination. The soil porosity, pH, and specific gravity
159 decreased significantly ($p \leq 0.05$) after the contamination (Table 2). From the results, the soil porosity
160 decreased from 35% to 14% (about 60% decreased), specific gravity decreased from 2.34 to 1.35
161 (about 50% decreased), while the soil pH decreased from 7.05 to 5.34, making the soil more acidic in
162 nature after the contamination. It can be seen from the results that the petroleum products increased
163 the bulk density of the soil samples. This could be attributed to the blockage of soil pores by the
164 pollutant. This result is similar to the previous studies of [14, 21] on spent lubricating oil contaminated
165 soil. In addition, [22] reported increase in the acidity and decrease in porosity of soils polluted with
166 crude oil. Furthermore, [23] stated that High hydrocarbon content of soils may affect the
167 physicochemical properties of the soil which may in turn affect the agricultural potentials and
168 productivities of such soils.

169

170 As seen in the results, the THC of the soil drastically increased from 0,923 mg/kg to 964.35 mg/kg,
 171 after the commination. In terms of heavy metals, the contaminated soil had significantly higher values
 172 than control soils ($p \leq 0.05$) with respect to total Cu, Fe and Pb. The copper level in the soil increased
 173 from 4.892 mg/kg to 7.729 mg/kg; the lead content increased from <0.0001 mg/kg to 1.128 mg/kg;
 174 while the iron content increased from 1251.2 mg/kg to 1587.9 mg/kg (Table 3). Similar result trend
 175 was reported by [22], where the copper content of soil sample increased from 16 mg/kg to 45.88; and
 176 the iron content increased from 314 mg/kg to 432.88 mg/kg after crude oil contamination. Ekundayo
 177 [24] reported a marked change in properties occurs in soils polluted with petroleum hydrocarbons,
 178 affecting the physical, chemical and microbiological properties of the soil.

179
 180 Table 2: Result of the impact of petroleum products on the physicochemical properties of soil

Parameters	Level	
	Before contamination	After contamination
Soil pH (H ₂ O)	7.05 ^a	5.34 ^b
Soil porosity (%)	35 ^a	14 ^b
Soil bulk density (kg/m ³)	2510 ^a	3120 ^b
Specific gravity	2.34 ^a	1.35 ^b
THC		
Soil sample (mg/kg)	0.923 ^a	964.35 ^b

181 Rows with the same common letter superscript are not significantly different at ($p \leq 0.05$).

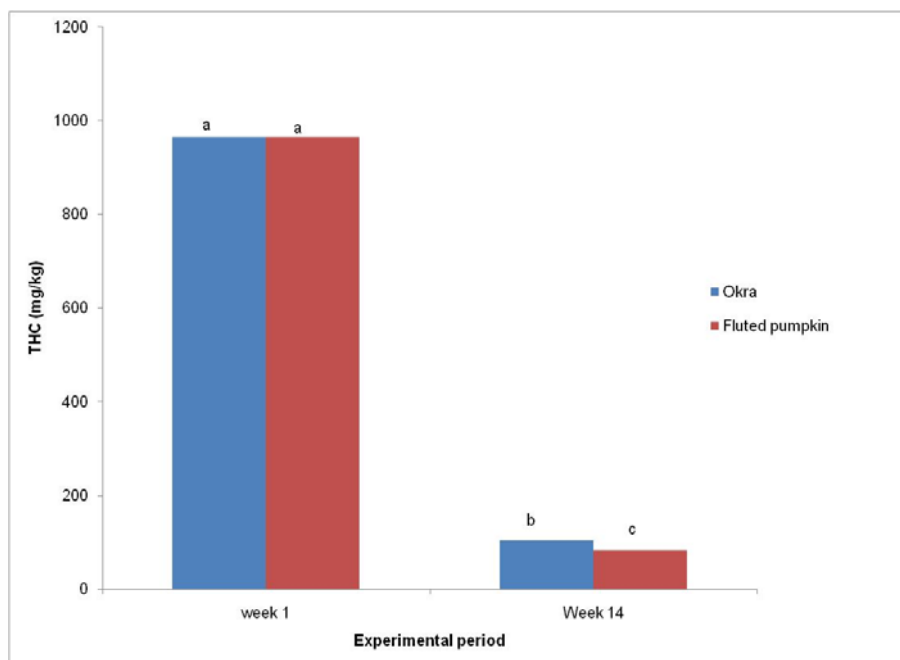
182
 183 Table 3: Result of the impact of petroleum products on the soil heavy metals

Parameters	Level	
	Before contamination	After contamination
Lead (mg/kg)	< 0.001 ^a	1.128 ^b
Copper (mg/kg)	4.892 ^a	7.729 ^b
Iron (mg/kg)	1251.2 ^a	1587.9 ^b

184
 185 **Phytoremediation potential of the plants**
 186 **THC degradation in the soil**

187 The results of the study presented in Figure 1, showed that the two plants were able to significantly (p
 188 ≤ 0.05) degrade the THC in the soil. From the results, it can be seen that the phytoremediation
 189 potential of *Telfairia occidentalis* was higher than *Abelmoschus esculentus*, after the 14 week
 190 experimental period. *Telfairia occidentalis* was able to degrade the THC in the soil from 964.35 mg/kg
 191 to 82.67 mg/kg; while *Abelmoschus esculentus* degraded the THC in the soil from 964.35 mg/kg to
 192 104 mg/kg. In similar result, *Telfairia occidentalis* degraded the TPH is a diesel contaminated soil by
 193 about 86.53 %, after 18 week experimental period [15]. Furthermore, the TPH concentrations of
 194 sandy soil decreased progressively from 18.8 to 11.4 mg/kg after phytoremediation using *Scirpus*
 195 *grossus* grass for 72 days [10]. The higher phytoremediation potential of fluted pumpkin over okra
 196 may be attributed to its extensive root network systems, higher foliage and better root biomass.

197
 198
 199



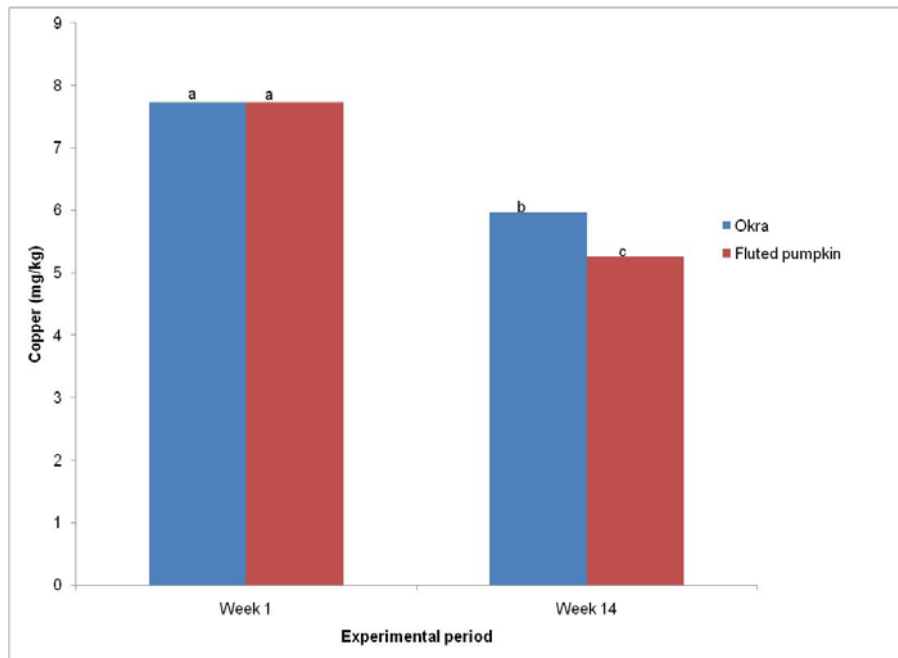
Different letters on columns represent statistical differences ($p < 0.05$) using Duncan's multiple range test.

Figure 1: Effect of phytoremediation crops on the THC of contaminated soil

Heavy metals content

The results of the degradation of the heavy metals by the plants are presented in Figures 2, 3 and 4. From the results, it can be seen that the two plants significantly degrade the heavy metals content in the soil. It was observed that *Telfairia occidentalis* had higher remediation potential as it was able to bring the copper content in the contaminated soil from 7.73 mg/kg to 5.26 mg/kg; while *Abelmoschus esculentus* degraded the copper content in the contaminated soil from 7.73 mg/kg to 5.97 mg/kg within the 14 week experimental period (Figure 2). In terms of the iron remediation in the soil, it was observed that the two plants were able to remediate the iron content in the contaminated soil. As shown in Figure 3, the *Telfairia occidentalis* was able to degrade the iron content in the contaminated soil from 1586.67 mg/kg to 1370.67 mg/kg, showing higher remediation potential against the *Abelmoschus esculentus*. In the results, *Abelmoschus esculentus* brought the concentration of iron in the contaminated soil from 1586.67 mg/kg to 1447.67 mg/kg.

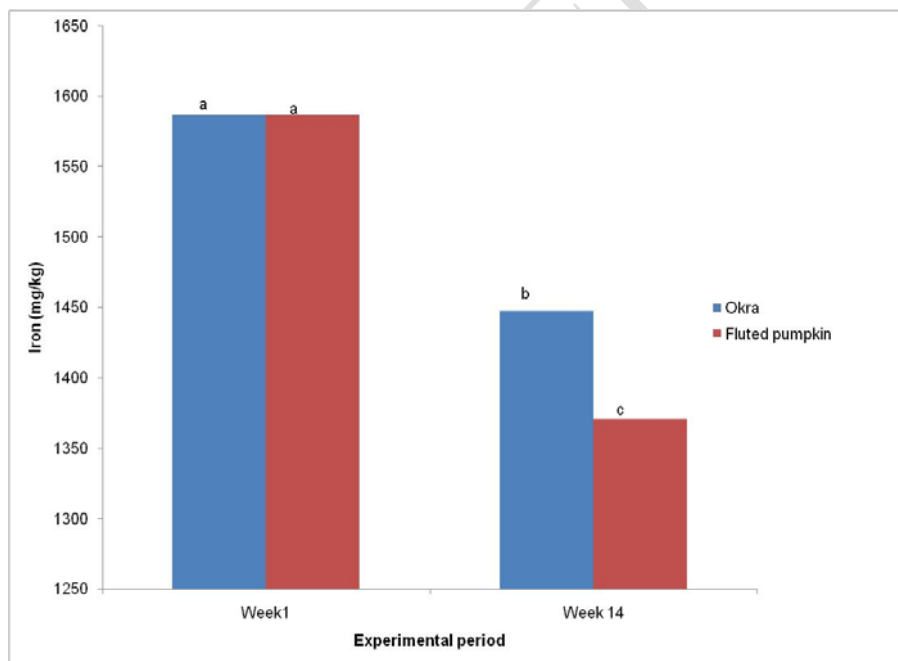
The results of analysis of the soil samples showed that there was significant ($p \leq 0.05$) improvement in the lead content of the contaminated soil after the experimental period. Results of the study presented in Figure 4, showed that *Telfairia occidentalis* had higher tendency of degrading the lead content in the soil. *Telfairia occidentalis* degraded the lead content from in the contaminated soil from 1.1277 mg/kg to 0.163 mg/kg; while *Abelmoschus esculentus* brought the content of lead in the contaminated soil from 1.1277 mg/kg to 0.4897 mg/kg. Some heavy metals at low doses are essential micronutrients for plants, but in higher doses they may cause metabolic disorders and growth inhibition for most of the plants species. Palmroth *et al.* [25] reported that root exudates from plants help to degrade toxic organic chemicals and act as substrates for bacteria in the soil, which improves the plants phytoremediation potential. Atlas and Bartha [26] suggested that it is the interaction between plants and micro-organisms which is the primary mechanisms responsible for petrochemical degradation in phytoremediation efforts.



231
232
233
234
235
236
237
238

Different letters on columns represent statistical differences ($p < 0.05$) using Duncan's multiple range test.

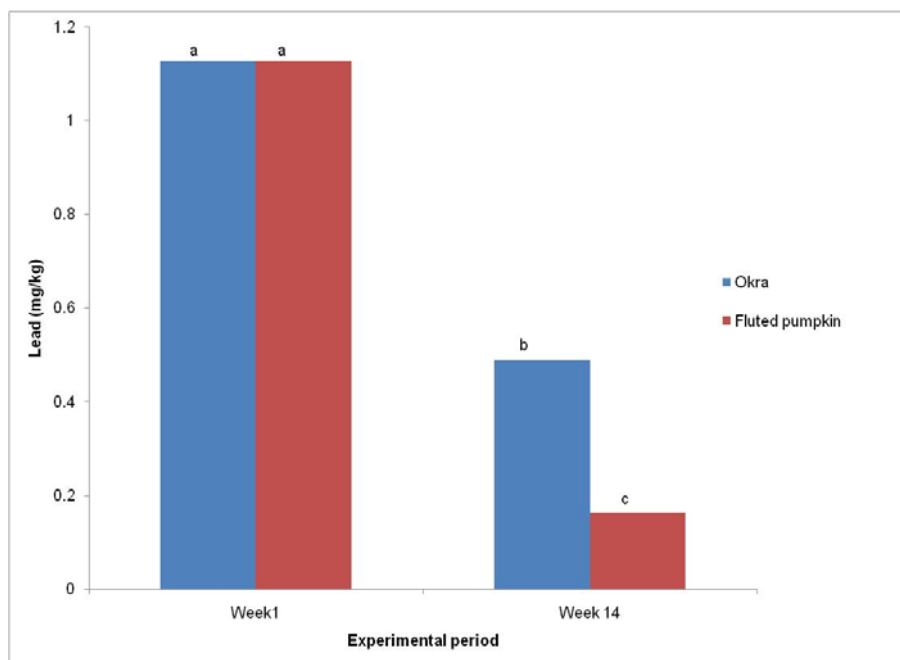
Figure 2: Effect of phytoremediation crops on the Copper content of contaminated soil



239
240
241
242
243
244
245

Different letters on columns represent statistical differences ($p < 0.05$) using Duncan's multiple range test.

Figure 3: Effect of phytoremediation crops on the Iron content of contaminated soil



Different letters on columns represent statistical differences ($p < 0.05$) using Duncan's multiple range test.

Figure 4: Effect of phytoremediation crops on the Lead content of contaminated soil

4.0 CONCLUSION

The present study investigated the effect of petroleum products on the physicochemical, THC and heavy metals content of agricultural soil, and its possible remediation using two vegetable crops. Results of the soil analysis showed that the petroleum products had significant ($p \leq 0.05$) adverse effects on the physicochemical properties, heavy metals and THC of the agricultural soil. Phytoremediation of the contaminated soil was carried out using fluted pumpkin (*Telfairia occidentalis*) and okra (*Abelmoschus esculentus*) within 14 week experimental period. Results obtained from the study showed that both vegetable crops had good phytoremediation potential, as they improved the soil conditions within the experimental period. Results obtained from the study showed that both crops had a good phytoremediation potential. However, fluted pumpkin (*Telfairia occidentalis*) had a higher potential than the okra (*Abelmoschus esculentus*). After the 14 week experimental period, *Telfairia occidentalis* was able to degrade the THC in the soil from 964.35 mg/kg to 82.67 mg/kg; while *Abelmoschus esculentus* degraded the THC in the soil from 964.35 mg/kg to 104 mg/kg. From the study results, laws banning indiscriminate disposal of petroleum products should be enforced; and more plants should be researched on to determine their phytoremediation potential.

REFERENCES

- [1] Odokuma L O, Ibor M N. Nitrogen fixing bacteria enhanced bioremediation of crude oil polluted soil. *Global Journ. Pure Appl. Sci.*, 2002, 8 (4): 455-468
- [2] Wang J, Jiq C R, Wong C K, Wong P K . Characterisation of polycyclic aromatic hydrocarbons created in lubricating oils. *Water, Air and Soil Pollution*, 2000, 120: 381-396
- [3] Abha S, Singh CS. Hydrocarbon Pollution: Effects on Living Organisms, Remediation of Contaminated Environments, and Effects of Heavy Metals Co-Contamination on Bioremediation, Introduction to Enhanced Oil Recovery (EOR) Processes and Bioremediation of Oil-Contaminated Sites, Dr. Laura Romero-Zerón (Ed.), 2012.
- [4] Peng S., Zhou Q, Cai Z, Zhang Z. Phytoremediation of petroleum contaminated soils by *Mirabilis Jalapa* L. in a greenhouse plot experiment. *J. Hazard. Mater.* 2009, 168, 1490–1496.
- [5] Agbogidi O M, Ejemeta O R. An assessment of the effect of crude oil pollution on soil properties, germination and growth of *Gambaya albida* (L). *Uniswa Research Journal of Agricultural Science and Technology*, 2005, 8(2): 148-155.
- [6] Agbogidi O M, Eshegbeyi O F. Performance of *Dacryodes edulis* (Don. G. Lam H.J.) seeds and seedlings in a crude oil contaminated soil. *Journal of Sustainable Forestry*. 2006, 22(3/4): 1-14.

- 284 [7] Liu X, Wang Z, Zhang X, Wang J, Xu G, Cao Z, Zhong C, Su P, (2011). Degradation of diesel-
285 originated pollutants in wetlands by *Scirpus triquetar* and microorganisms. *Ecotoxicol. Environ.*
286 *Saf.*, 2011, 74, 1967–1972.
- 287 [8] Akpokodje O I, Uguru H, Esegbuyota D. Evaluation of phytoremediation potentials of different
288 plants' varieties in petroleum products polluted soil. *Global Journal of Earth and Environmental*
289 *Science*, 2019, 4(3): 41-46.
- 290 [9] Huesemann M, Hausmann T, Fortman T, Thom R, Cullinan V. In situ phytoremediation of PAH-
291 and PCB-contaminated marine sediments with eelgrass (*Zostera marina*). *Ecol. Eng.* 2009, 35,
292 1395–1404.
- 293 [10] Al-Baldawi I A., Abdullah S R S, Anuar N, Suja F, Mushrifah I. Phytodegradation of total
294 petroleum hydrocarbon (TPH) in diesel-contaminated water using *Scirpus grossus* . *Ecological*
295 *Engineering* , 2015, 74 : 463–473
- 296 [11] Schnoor J L. Technology evaluation report: phytoremediation of soil and groundwater. GWRTAC
297 Series, 2002.
- 298 [12] Njoku K L; Akinola M O, Oboh B O (2009). Phytoremediation of crude oil contaminated soil: the
299 effect of growth *Glycine max* on the physio-chemistry and crude oil content of soil. *Nature and*
300 *Science*, 2009, 7 (10): 79-87
- 301 [13] Ndimele P E. Evaluation of phyto-remediative properties of water hyacinth (*Eichhornia crassipes*
302 [Mart.] Solms) and biostimulants in restoration of oil-polluted wetland in the Niger Delta. Ph.D.
303 Thesis, University of Ibadan, Nigeria. 2008.
- 304 [14] Kayode J, Oyediji A A, Olowoyo O. Evaluation of the Effects of Pollution with Spent Lubricating
305 Oil on the Physical and Chemical Properties of Soil. *The Pacific Journal of Science and*
306 *Technology*, 2009, 10(1): 387-391
- 307 [15] Akpan G U, Usuah P E. Phytoremediation of Diesel Oil Polluted Soil by Fluted Pumpkin (*Telfairia*
308 *Occidentalis Hook F.*) in Uyo, Niger Delta Region, Nigeria. *Journal of Environment and Earth*
309 *Science*, 2014, 4(1):6 - 15
- 310 [16] Association of Analytical Communities (AOAC). Official Methods of Analysis. 15th Edn.
311 Association Official Analytical Chemists. Washington D.C., 1990, 805-845
- 312 [17] ASTM D 9071B - 7. *Hexane Extractable Materials using Soxhlet Extraction Method*, American
313 Society for Testing and Materials
- 314 [18] APHA - American Public Health Association. *Standard Methods for Examination of Water and*
315 *Wastewater*, 16th Edition, Washington DC. 1005.
- 316 [19] Akpokodje O I, Uguru H, Esegbuyota D. Remediation of cassava effluent contaminated soil
317 using organic soap solution: case study of soil physical properties and plant growth performance.
318 *Journal of Scientific Research and Reports*, 2018, 21(3), 1-11,
- 319 [20] Frick C M, Farrell R E, Germida J J. Assessment of phytoremediation as an in situ technique for
320 cleaning oil-contaminated sites. PTAC Petroleum Technology Alliance, Canada, Calgary. 1999
- 321 [21] Udonne J D, Onwuma H O. A study of effects of waste lubricating oil on the physical/chemical
322 properties of soil and the possible remedies. *Journal of Petroleum and gas Engineering*, 2014,
323 5(1): 9-14
- 324 [22] Andrade M L, Covelo E F, Vega F A, Marcet P. Effect of the Prestige Oil spill on salt marsh soils
325 on the coast of Galicia (Northwestern Spain). *Journ. Environ. Qual.* 2004, 33, 2103 – 2110
- 326 [23] Amadi A, Dickson A, Maate G O. Remediation of oil polluted soils: effects of organic and
327 inorganic nutrient supplements on the performance of maize. *Water, air and soil pollution*, 1993,
328 66: 59 – 76
- 329 [24] Ekundayo J A, Aisueni N, Benka-Coker M O. The Effects of drilling fluids in some waste and
330 burrow pits in western operational areas of Shell Petroleum Development Company of Nigeria
331 Limited on the soil and water quality of the areas. Environmental Consultancy Service Group,
332 Consultancy Services Unit, University of Benin, Benin City, Nigeria. 1989.
- 333 [25] Palmroth M R, Pichtel J, Puhakka JA. Phytoremediation of subarctic soil contaminated with diesel
334 fuel. *Bioresour. Technol.* 2002, 84, 221–228.
- 335 [26] Atlas R M, Bartha R. *Microbial Ecology: Fundamentals and Applications*. 4th Edn., Benjamin
336 Cummings, USA., 1998.
- 337