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Assessing the Potential of *Parkia biglobosa* (Jacq.) R.Br. ex. G. Don - A Leguminous Plant Species commonly found in Nigeria to Decontaminate Crude Oil-polluted Soil in Terrestrial Ecosystem

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ABSTRACT: The potentials of *Parkia biglobosa* (a leguminous plant species) to decontaminated crude oil-polluted soil in terrestrial ecosystem was evaluated in this study using appropriate standard techniques to estimate seedling germination, height, collar diameter, number of leaves and physicochemical characteristics (organic matter, pH, calcium, magnesium and sodium, nitrogen, phosphorous and potassium) of soil used, were determined using standard protocols. Results indicated that varying concentration of crude oil influenced the variables measured. For 0 ml, 25 ml, 50 ml, 75 ml and 100 ml crude oil treatments, *Parkia biglobosa* had 18%, 18%, 16%, 13% and 11% germination rate correspondingly; mean height of 38.70cm, 26.80cm, 21.20cm, 18.50cm and 6.80cm respectively, mean collar diameter of 0.32mm, 0.30mm, 0.26mm, 0.24mm and 0.22mm respectively; 2, 0, 0, 0 and 0 nodules count respectively, and 8.00, 6.00, 5.00, 5.00 and 2.00 leaf count respectively. All physicochemical parameters measured decreased in the soil in inverse proportion to crude oil concentration. So also, seedling germination, height, collar diameter, number of leaves and nodulation decreased in inverse proportion to crude oil concentration. *Parkia biglobosa* grew tolerably in both high and low concentrations of crude oil, which is an indication of its able to withstand crude oil toxicity. *Parkia biglobosa* as a nitrogen fixing plant would be a good candidate for the terrestrial restoration of crude oil contaminated regions in Nigerian.

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Crude oil pollution is an environmental threat recognized globally, since the first strike of oil and the evolution of its applications, from heating to modern style of commutation. Contamination of agricultural soils with pollutants like heavy metals has always been considered a critical challenge in scientific community (Faruk *et al*., 2006). Due to the cumulative behaviour and toxicity, such pollutants have a potential hazardous effect not only on human health but also on crop plants (Das *et al*., 1997). Hence there is need for urgent clean-up of such polluted environment. Exploration of fossil fuels have been on the increasing trends in the world especially in major producing nations due to increase in demand of crude oil products such as gasoline, kerosene, diesel etc. Crude oil production in Nigeria is about 1.5 million barrels per day and reserve is about 37.1 billion barrel (EIA, 2023). Crude oil spill have been reported. Oil spill

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occur during exploration, production, refining, Transportation, distribution, marketing of petroleum products. The presence of crude oil in the environment has caused several adverse impacts on the environment (Seiyaboh and Izah, 2017; Onwuna et al., 2022), leading to variation in microbial, physiochemical, heavy metal and hydrocarbon content of the soil which in turn may affects the biological components of the ecosystem including microbes, insects, vegetation and wildlife, which in the case of the Niger Delta led to a reduction the productive quality of the terrestrial ecosystem (UNEP, 2011). It also leads to habitat alteration, and death and indirect leading to loss of food resources (Oyedeji *et al*., 2012; Oyedeji, *et al*., 2015). The volatile fraction of the crude oil has the tendency to aerosolize be inhaled by humans that reside close to the vicinities of oil and gas operation or where crude oil or its derivatives spill. Crude oil also has the tendency to contaminate drinking water sources of humans (Aigerua *et al*., 2017). Thus, the adversative effects of crude oil pollution can transcend all trophic levels. These adverse impacts of crude oil on the environment and human health make environmentalists clamor for cleanup. They have tried several methods of remediation available depending on the environmental matrix and physical constituents of the crude oil. Among these are the use of surfactants, dispersant, microbes and plants. Phytoremediation which is the process of exploiting the propensity of plants to sop up, accrue, depollute and make pollutants nontoxic, by employing their root and transport systems, rhizosphere microbiota and biomass via a combination of biological, chemical or physical processes (Cunningham and Berti, 1993), is an asset for terrestrial ecosystem restoration (Bamidele and Agbogidi, 2006). Although petroleum hydrocarbons can adversely affect the growth of plants, the degree of harm depends of the plant species as tolerance to pollutant differ among plants (Hoang et al., 2021). Oyedeji (2016) reported the tolerance of leguminous crops to high concentrations of hydrocarbons and suggested their suitability in terrestrial ecosystem restoration. Information about phytoremediation potentials of *Parkia biglobosa* appears scanty in literature. Therefore, the aim of this study is to evaluate the potential of *Parkia biglobosa* (Jacq.) R.Br. ex. G. Don - a leguminous plant species commonly found in nigeria to decontaminate crude oil-polluted soil in terrestrial ecosystem.

MATERIALS AND METHODS

Study sites: The study was in the Screen House of the Department of Biological Sciences, Niger Delta University, Nigeria.

Source of samples: *Parkia biglobosa* seeds was provided by the National Centre for Genetic and Biotechnology (NAGRAB), Ibadan, Nigeria. Crude oil was obtained from Oporoma Flow Station operated by Shell Petroleum Development Company, Nigeria.

Germination test: Viable *P. biglobosa* seeds ascertained by the afloat method of Anoliefo and Vwioko (1995), were planted in five plant bags holding 3000 g of clay-loamy collected from the Experimental Farm of the Niger Delta University, Nigeria, from 0-10 cm soil depth.

There were five treatments in the study, 0%, 25%, 50%, 75% and 100% crude oil concentrations. Aqueous soil extract of the five treatments were obtained and used to imbrue the seeds in the seeds as described by Oyedeji and Oyedeji (2022). The test was set in five replicates with ten seeds per petri dish. The seeds were watered daily germination rate determined on the 10th day using the formula 1:

$$Gt = \frac{\text{Number of seedlings that emerged/dish}}{\text{Total number of seeds sown}} * 100 \quad (1)$$

Where Gt = Germination test

Growth response test: The method of Oyedeji and Oyedeji (2022) was adopted. Three viable seeds of *P. biglobosa* were sown in each bag and watered daily. Plant per bag 2 weeks after planting (WAP) was pruned to one. Growth parameters (height, collar diameter, number of leaves and nodulation) were measured fortnightly from 2 WAP to 16 WAP. The relative growth rate (RGR) was estimated from mean heights. The percentage growth suppression was also calculated (Oyedeji and Oyedeji, 2022).

Soil physical properties: Soil physicochemical properties were determined following standard methods for volume of air in soil, soil water capillarity and porosity (Akinsanmi, 1975); moisture content (Osuji and Onojake (2004); soil nitrogen, calcium and magnesium (Anderson and Ingram, 1996); soil organic matter, pH and bulk density (Ibitoye, 2006), and phosphorous (Bray and Kurtz, 1945).

RESULTS AND DISCUSSION

The percentage germination of *P. biglobosa* contaminated with crude oil is presented in Figure 1. At varying concentration of 0 ml, 25 ml, 50 ml, 75 ml and 100 ml of crude oil on germination of *P. biglobosa* was 18% (15 COV), 18% (13 COV), 16% (11 COV), 13% (10 COV) and 11% (10 COV) respectively. The findings is in congruence with the report of Adeyemi and Adeyemi (2020) that seedling growth is affected by crude oil concentration. With a percentage germination rate of 11% at 100% crude oil concentration and 18% at 0% and 25% hydrocarbon concentrations, *P. biglobosa* could be said to tolerate high petroleum hydrocarbon concentration. Oyedeji (2016) reported the tolerance of leguminous crops to high concentrations of hydrocarbons and suggested their suitability in terrestrial ecosystem restoration. Germination is the most decisive phase of the life cycle any crop, as the crop must first sprout before it can build biomass and carryout other physiological functions. However, under environmental stress condition, plants germination and growth can be severely suppressed, such as in the presence of petroleum hydrocarbons (Sangeetha and Thangadurai, 2014). Hydrocarbon can osmotic relation between seed (Sangeetha and Thangadurai, 2014). As per the reports by Bamidele and Agbogidi (2006) and Okon and Udofot et al. (2012), seed growth is dependent on seedling germination as later initiates establishment of the plants, and this phase is sensitive to environmental stresses. The toxic constituents present in crude oil can disrupt cellular processes, impede water absorption, alter nutrient availability, and induce oxidative stress, leading to poor germination rates and compromised seedling growth (Okon and Udofot, 2012; Sangeetha and Thangadurai, 2014; Adeyemi and Adeyemi, 2020). Mean girths of *P. biglobosa* grown in crude oil-polluted soil is presented in Table 2 below. Seedlings of *P. biglobosa* grown in the treated soil had girth values of 0.32±0.01mm, 0.30±0.03mm, 0.26±0.04mm, 0.24±0.06mm and 0.22±0.06mm for 0ml, 25 ml, 50 ml, 75ml and100 ml respectively at16 WAP. This is consistent with the pertain of decrease in height with an increase in the concentrations of crude oil in the soil. Bioremediation Table 3 leaf numbers and number of nodules of *P. biglobosa. P. biglobosa* did not produce nodules both at low and high concentrations of crude oil. While in the control only 2 nodules were detected.

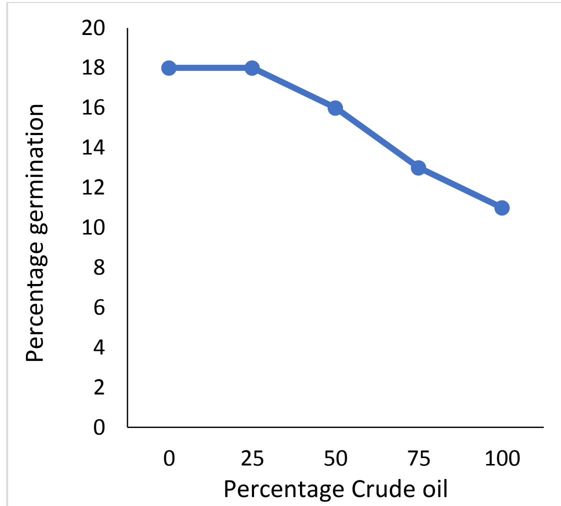

Fig 1: Percentage germination of *P. biglobosa*

Table 1 shows the mean heights of *P. biglobosa* grown in crude oil-polluted soil. Mean heights of the species were 1.50±0.80cm, 2.60±1.54cm, 2.95±1.68cm, 0.00±0.00cm and 0.00±0.00cm in the 0, 25, 50, 75 and 100 % crude oil-spiked soil respectively at 2 WAP. At 16 WAP, the heights obtained were 38.70±2.10cm, 26.80±1.75cm, 21.20±1.68cm, 18.50±1.64cm and 6.80±2.40cm in 0, 25, 50, 75 and 100 % crude oil-spiked soils respectively. This is in conformity with the reports by Anoliefo and Okoloko (2000) and Okon and Udofot (2012) where it was affirmed that presence of crude oil in high amounts significantly inhibited plant growth reduction. Osuagwu *et al*. (2013) crude oil affect photosynthetic pigments, thus impairing the plants' ability to carry out photosynthesis and adversely affecting their growth.

Table 1: Mean number of plant height of *P. biglobosa*

Time	Plant height (cm)/Crude oil concentration (ml)				
(WAP)	0	25	50	75	100
2	1.50±0.80	2.60±1.54	2.95±1.68	0.00±0.00	0.00±0.00
4	3.60±1.40	5.20±1.45	6.30±1.56	0.00±0.00	0.00±0.00
6	5.10±1.85	8.10±1.30	9.50±1.60	3.50±1.48	0.00±0.00
8	7.20±1.72	9.15±1.50	11.57±1.56	6.80±1.57	0.50±0.00
10	15.50±1.82	12.50±1.62	14.60±1.75	8.20±1.61	2.50±1.00
12	18.50±1.78	16.20±1.30	18.10±1.70	10.40±1.75	3.60±1.80
14	25.60±1.85	22.50±1.64	20.70±1.50	11.00±1.98	5.40±2.20
16	38.70±2.10	26.80±1.75	21.20±1.68	18.50±1.64	6.80±2.40
∑X±SD	**115.70±13.32**	**103.05±12.10**	**104.92±13.03**	**58.40±10.03**	**18.80±5.40**
$\Delta H = H_F - H_I$	**37.2±1.30**	**24.2±0.21**	**18.25±0.00**	**18.5±1.64**	**6.8±2.40**
RGR	**0.23**	**0.17**	**0.14**	**0.00**	**0.00**
GS	**0.00**	**0.307**	**0.452**	**0.522**	**0.824**
%GS	**0.00**	**30.70**	**45.20**	**52.20**	**82.40**

RGR = Relative growth rate; GS = growth suppression; H_I = Initial Height; H_F = Final Height; ΔH = Change in height; $\overline{X}$ = Mean; (±) = Standard deviation

The number of leaves in increasing order of crude oil concentration were 8.00, 6.00, 5.00, 5.00 and 2.00 respectively. Nodulation is a significant adaptation for nitrogen fixing plants, with regards to their growth requirement. Absence of nodulation is a pointer to severe impairment of physiological and morphological properties of the plant. Also, a reduction in leaves as a result of the presence of crude oil in soil implies that food production of the plant would be affected (Osuagwu *et al*. (2013) which would invariably affect plant girth. This observation is consistent with the findings of Anoliefo and Okoloko (2000) with regards to the growth of *Cucumeropsis manni*, and Oyedeji and Oyedeji (2022) with regards to the growth of *Albizia procera*. Crude oil compromises the symbiotic nodulation process with nitrogen-fixing bacteria (John et al., 2016). Hoang et al. (2021) affirmed that the activities of endophytic microbial communities enhances the removal of hydrocarbons by plant. According to Ali et al. (2023) nutrient uptake by plant during bioremediation is enhanced by endophytic microbes, while the microbes reduce the toxicity of the pollutant to the plants. Thus, absence of nodules would limit the hydrocarbon removal efficiency of *P. biglobosa.*

Table 2: Mean girths of *P. biglobosa*

Experimental Time (WAP)	Plant girth (mm)/Crude oil concentration (ml)				
	0	25	50	75	100
2	0.12±0.02	0.11±0.02	0.11±0.03	0.11±0.02	0.10±0.03
4	0.14±0.03	0.13±0.03	0.12±0.02	0.11±0.04	0.11±0.04
6	0.16±0.04	0.14±0.02	0.13±0.04	0.13±0.01	0.13±0.02
8	0.18±0.01	0.16±0.04	0.14±0.05	0.14±0.02	0.13±0.06
10	0.22±0.05	0.19±0.05	0.16±0.01	0.15±0.05	0.14±0.07
12	0.24±0.03	0.22±0.01	0.20±0.06	0.18±0.03	0.16±0.05
14	0.27±0.06	0.24±0.05	0.22±0.03	0.20±0.04	0.18±0.03
16	0.32±0.01	0.30±0.03	0.26±0.04	0.24±0.06	0.22±0.06
$\Delta G=G_F-G_I$	**0.20±0.01**	**0.19±0.01**	**0.15±0.01**	**0.13±0.04**	**0.12±0.03**
$\sum X \pm SD$	**1.65±0.25**	**1.49±0.25**	**1.34±0.28**	**1.26±0.27**	**1.17±0.36**

Table 3: Mean number of leaf and nodules of *P. biglobosa*

	Crude oil concentration (ml)							SD
Parameter	0	25	50	75	100	Mean	Variance	
Leaf	8.00	6.00	5.00	5.00	2.00	5.20	4.70	217
Nodule	2.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00

The physiochemical characteristics of soil used to grow *P. biglobosa* after treatments, are presented in Table 4. The soil pH was in the range of 5.04 (at 0 ml) and 4.52 (100ml). Soil pH is critical for plant growth as well as for the survival of all soil organisms. The pH was generally acidic and the acidity increased with the concentration of the crude oil. This agrees with the position of Oyedeji and Kayode (2020) that crude oil contamination can lead to changes in soil pH, making it more acidic. The organic matter concentration ranged 1.64% (0 ml) - 1.34% (100ml), decreasing inversely to the amount of crude oil present in the soil. Organic matter content of soils have far-reaching implications for soil health, such that a reduction in organic matter is taken as an indicator of pollution, especially as it implies a depletion of organism responsible for its formation (Osuji and Adesiyan, 2005). The concentration of nitrogen, phosphorus and potassium also decreased as the concentration of the crude oil increased. The concentrations were in the range of 0.47 % (0 %) – 0.36% (100 %) (Nitrogen), 6.51 mg/kg (0 %) – 4.82 mg/kg (100 %) (Phosphorous) and 3.31 mg/kg (0 %) – 2.56 mg/kg (100 %) (Potassium). The concentration of sodium were in the range of 2.31 mg/kg (0 %) – 2.58 mg/kg (100ml), calcium were in the range of 16.50 mg/kg (0 %) – 12.90 mg/kg (100 %) and magnesium was in the range of 1.85 mg/kg (0 %) – 1.58 mg/kg (100 %). Oyedeji and Oyedeji (2022) similarly reported that crude oil-contaminated soils reduced soil pH, organic matter content, and cation exchange capacity. Onyeike et al. (2009) reported in their study of soil and water in Ogoni, that inorganic ion levels of soil decreased as a result of crude oil pollution.

Table 5 shows the effect of physical properties of unpolluted and crude oil-polluted soil used in the experiment. Bulk density of 5.80, 6.40, 6.40, 6.8 and 7.70 g/cm^3 were observed in the treatments 0, 25, 50, 75 and 100 % crude oil-polluted soil respectively. Soil moisture content reduced in the crude oil-polluted soil samples particularly in the 100 ml crude oil-contaminated soil. Similarly, the presence of crude oil in the soil samples affects the soil air, 72.50, 38.60, 30.50, 40.40 and 43.60 % were observed in 0, 25, 50 75 and 100 ml respectively. Water holding capacity was also reduced in the crude oil-polluted soil. This is consistent with the reports by Oyedeji and Kayode

(2020), and Oyedeji and Oyedeji (2022), where it was reported that the presence of crude oil in soil affects the physical properties of soil, in such a way that as the concentration of the crude oil increased, the soil bulk density, moisture content, soil air, water holding capacity and porosity reduced in the polluted soil.

Table 4: Physiochemical characteristics of crude oil-contaminated soil

	Crude oil concentration (ml)				
Parameters	0	25	50	75	100
pH	5.04	4.82	4.65	4.57	4.52
Organic matter, %	1.64	1.61	1.54	1.50	1.34
% N	0.47	0.44	0.41	0.36	0.36
P, mg/kg	6.58	6.45	6.15	5.88	4.82
K, mg/kg	3.31	3.25	2.80	2.36	2.56
Na, mg/kg	2.31	2.30	2.18	2.78	2.58
Ca, mg/kg	16.50	15.60	14.90	12.90	12.90
Mg, mg/kg	1.85	1.75	1.65	1.58	1.58

Table 5: Physical properties of unpolluted and crude oil-polluted soil

Crude oil (ml)	Moisture content (%)	Bulk Density (g/cm^3)	Soil porosity (ml)		Soil air (%)	Water Holding capacity (ml)
0	5.8	72	72.5	58.4	86.4	5.8
25	6.4	44.5	38.6	50	81.5	6.4
50	6.4	40	30.5	34.5	60.4	6.4
75	6.8	28.5	40.4	24.1	48.3	6.8
100	7.7	18.2	43.6	13.7	32.8	7.7

Conclusion: Crude oil affects soil physicochemical characteristics (especially nitrogen, phosphorous, calcium, sodium, magnesium, potassium organic matter) especially at very high concentrations. *P. biglobosa* tolerated crude oil with regard to germination, height, leaf number and nodulation, which decreased as the concentration of the crude increased. The ecological significance of *P. biglobosa* as a hydrocarbon tolerant plant has been established and this could guide environmental remediation strategies in the Niger Delta.

REFERENCES

Adeyemi, O; Adeyemi, O (2020). Effect of Crude Oil Contaminated Soil on *Phaseolus vulgaris* L. *World J. Inter. Res.* 8(2): 28-33

Aigberua, AO; Ekubo, AT; Inengite, AK; Izah, SC (2016). Seasonal variation of nutrient composition in an oil spill contaminated soil, a case of Rumuolukwu, Eneka, Port Harcourt, Nigeria. *Biotechnol. Res.* 2(4): 179-186.

Akinsanmi, O (1975). Certificate Agricultural Science. 1st Ed, Longman Group Ltd, Nigeria.

Ali, MH; Khan, MI; Naveed, M; Tanvir, MA (2023). Microbe-assisted rhizoremediation of hydrocarbons and growth promotion of chickpea plants in petroleum hydrocarbons-contaminated soil. *Sustainability*. 15(7): 6081. DOI: https://doi.org/10.3390/su15076081

Anderson, JM; Ingram, JSI (1996). Tropical soil biology and fertility. *A Handbook of soil methods.*2nd Ed. CAB International Information Press, Eynsham, pp. 221

Anoliefo, GO; Okoloko, GE (2000). Comparative toxicity of Forcados Blend crude oil and its water-soluble fraction on seedlings of *Cucumeropsis manni* Naudin. *Nig. J. Appl. Sci.* 18:39-49

Anoliefo, GO; Vwioko, DE (1995). Effect of spent lubricating oil on the growth of *Capsicum annuum* L. and *Lycopersicon esclentum*, Mill. *Environ. Pollut.* 88:361-364

Bamidele, J; Agbogidi, O (2006). The effect of soil pollution by crude oil on seedling growth of (L) GFW Meg. *Discov. Innov.* 18(2):104-108

Bray, RH; Kurtz, LT (1945). Determination of total organic and available forms of phosphorous in the soils. *Soil Sci.* 59:39-45

Cunningham, SD; Berti, WR (1993). Remediation of contaminated soi1 with green plants: an overview. *In Vitro Cell Dev. Biol*. 29: 207-21

Das, PS; Samantaray, GR; Rout, GR (1997). Studies on Cadmium toxicity in plants: A review. *Environ. Pollu.* 98: 29-36

Faruk, OS; Nazin, SM; Kara, S (2006). Monitoring of Cadmium and Micronutrients in spices commonly consumed in Turkey. *Res. J. Agric. Biol. Sci*. 2: 223-226

Hoang, SO; Lamb, D; Seshadri, B; Sarkar, B; Cheng, Y; Wang, L; Bolan, NS (2021). Petroleum hydrocarbon rhizoremediation and soil microbial activity improvement via cluster root formation by wild proteaceae plant species. *Chemosphere*. 275:130135. DOI: https://doi.org/10.1016/j.chemosphere.2021.130135.

John, RC; Ntino, ES; Itah, AY (2016). Impact of crude oil on soil nitrogen dynamics and uptake by legumes grown in ultisol of the Niger Delta, Nigeria. *J. Environ. Protect.* 7(4): 507-515.

Onwuna, B; Stanley, HO; Abu, GO; Immanuel, OM (2022). Impact of Artisanal Crude Oil Refinery on Physicochemical and Microbiological Properties of Soil and Water in Igia-Ama, Tombia Kingdom, Rivers State, Nigeria. *Asian J. Environ. Ecol.* 19(3): 48-59.

Osuagwu, AN; Okigbo, AU; Ekpo, IA; Chukwurah, PN; Agbor, RB (2013). Effect of Crude Oil Pollution on Growth Parameters, Chlorophyll Content and Bulbils Yield in Air Potato (*Dioscorea bulbifera* L.). *Inter. J. Appl. Sci. Technol.* 3(4): 37-41.

Osuji, LC; Adesiyan, SO (2005). The Isiokpo oil-pipeline leakage: Total organic carbon/organic matter contents of affected soils. *Chem. Biodiv.* 2:1079-1085

Osuji, LC; Onojake, CM (2004). Trace heavy metals associated with crude oil: A case. *Chem. Biodiv.* 1:1708-1715.

Oyedeji AA; Adebiyi, AO; Omotoyinbo, MA; Ogunkunle, CO (2012). Effect of crude oil-contaminated soil on germination and growth performance of *Abelmoschus esculentus* L. Moench—a widely cultivated vegetable crop in Nigeria. *Am. J. Plant Sci.* 3: 1451-1454

Oyedeji, AA; Kayode, J; Besenyei, L; Fullen, MA (2015). Germination of seeds of selected leguminous tree species moistened with varying concentrations of crude oil-contaminated soil water extracts. *Am. J. Plant Sci.* 6: 1575-1580

Oyedeji, AA; Kayode, J (2020). Phytoremediation: assessment of *Afzelia africana* germination and growth performance in crude oil contaminated soil. *FUW Trends in Sci. Technol. J.* 5(2): 403 – 406.

Oyedeji, AA; Oyedeji, OF (2022). Assessment of phytoremediation potentials of *Albizia procera* (Roxb.) Benth, A leguminous plant species in crude oil-polluted soil rehabilitation. *FUW Trends. Sci. Technol. J.* 7(3): 48 – 54.

Oyedeji, AA; Besenyei, L; Kayode, J; Fullen, MA (2022). An appraisal of phytoremediation as an alternative and effective remediation technology for crude oil-contaminated soils, A review. *Afr. J. Environ. Sci. Technol.* 16 (8): 311-319.

Onyeike, EN; Ogbuja, SI; Nwinuka, NM (2000). Inorganic ion levels of soils and streams in some areas of Ogoniland, Nigeria as affected by crude oil spillage. *Environ. Monitor. Assess.* 73: 1991-2125.

Sangeetha, J; Thangadurai, D (2014). Effect of biologically treated petroleum sludge on seed germination and seedling growth of *Vigna unguiculata* (L.) Walp. (Fabaceae). *Environ. Sci. Braz. Arch. Biol.Technol*. 57 (3). DOI: https://doi.org/10.1590/S1516-89132014005000011

Seiyaboh, EI; Izah, SC (2017). A Review of Impacts of Gas Flaring on Vegetation and Water Resources in the Niger Delta Region of Nigeria. *Inter. J. Econ., Energy. Environ.* 2(4): 48-55

.

US Energy Information Administration (2023). International energy statistics database. http//: www.eia.gov/international/content/analysis/countries_long/Nigeria/

UNEP (2011). Environmental Assessment of Ogoniland. Available at http://www.unep.org/disastersandconflicts/countryOperations/Nigeria/EnvironmentalAssessmentofOgonilandreport/tabid/54419/Default.aspx. A