American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-12, pp-180-185
www.ajer.org
Research Paper Open Access

Performance of Irrigated Maize in A Crude-Oil Polluted Soil Remediated By Three Nutrients In Nigeria's Niger Delta

[*1]Fubara-Manuel, I.,[2]Igoni, A. H.,[3]Jumbo, R. B.
Department of Agricultural and Environmental Engineering, Rivers State University, Port Harcourt, Nigeria
Corresponding Author: Fubara-Manuel, I.

ABSTRACT: *An in-situ simulated crude-oil polluted soil was remediated for 8 weeks by three different nutrients, and then used to plant maize (Farz 26) with a growth period of 14 weeks, with an irrigation depth of 4mm/day. Remediation consisted of the application of 16.667, 22.222, and 27.778 t/ha of NPK (15:15:15) fertilizer, spent mushroom substrate (SMS), and pig slurry (PS) to the polluted soil, laid out in randomized complete block design, with three replications, including a control that was neither polluted nor treated. Physico-chemical and microbial properties of the soil before and during remediation, and growth parameters of the maize were determined. Results indicated that 8 weeks after remediation, 27.778 t/ha of NPK, PS, and SMS reduced total hydrocarbon content (THC) by 87.3, 91.2, and 88.6% respectively. For maize, 14 weeks after planting resulted in a yield of 1.11, 1.20, and 1.17 t/ha from the soil remediated by 27.778 t/ha of NPK, PS, and SMS respectively, while the control yielded 2.58 t/ha. The difference in yields between the control and the remediated soils was significant at 5% level. The result indicated a 53.5% reduction in yield mainly due to the non-restoration of the soil to its original status.*

Keywords: *Crude – oil, maize, pollution, remediation, yield*

Date of Submission: 21-11-2017 Date of acceptance: 16-12-2017

I. INTRODUCTION

The Niger Delta region of Nigeria produces more than 98% of Nigeria's crude-oil [1]. Commercial exploration, which started in 1958 [2], has continuously led to increasing soil infertility due to oil spillage arising mainly from lack of pipeline maintenance by oil prospecting companies, and/or sabotage by host communities due to perceived injustice and unequal distribution of the oil wealth. Crude – oil contaminated soil may remain unsuitable for plant growth for months or years, depending on the degree of contamination [3]. As oil spills on the soil, it penetrates easily to the depth of 10-20cm, a depth range usually considered vital for agricultural activities. Rainfall and ground water fluctuations provide the opportunity for migration of the crude oil from the polluted site, causing extensive threat to the surrounding ground which, in turn, threatens human health and those of the organisms that are dependent on the soil [4]. Furthermore, some of the pollutants remain trapped in the pore spaces of the soil, forming films between the soil grains thereby reducing the rate of infiltration [5; 6]. Changes in soil properties due to contamination with petroleum -derived substances can also lead to water and oxygen deficits as well as shortages of available forms of nitrogen and phosphorus [7]. All of these are detrimental to crop production.

The search for cheaper and environmentally friendly options of enhancing petroleum hydrocarbon degradation has continued to elicit research interest [8]. Thus, bioremediation, which involves the use of micro-organisms via addition of fertilizers to improve their numbers or the direct addition of micro-organisms, has been studied as a means of remediating the harmful effect of crude-oil pollution [9]. The involvement of micro-organisms in the degradation of petroleum and its products has been established as an efficient, economic, versatile and environmentally sound treatment [10]. Addition of organic materials such as poultry and green manure singly or in combination to improve the chemical properties of the oil-polluted soil will enhance the solubility and removal of the contaminants, thus improving biodegradation rates [11]. Maize is an important food crop grown in the Niger Delta region of Nigeria. Its production is, however, limited by farmers' total dependence on rain-fed agriculture. The crop is therefore grown only during the rainy season. Maize is quite sensitive to water stress, and shows different responses to water deficiency in different developmental stages [12]. The objective of this research, therefore, is to remediate a crude oil polluted soil, using three different nutrients during the dry season, with a view to ascertaining the performance of irrigated maize on the soil remediated by each of the three nutrients.

II. MATERIALS AND METHODS

2.1 Description of the study area

The study was conducted at the Teaching and Research Farm of the Rivers State University, Port Harcourt, Nigeria, during the dry season between November, 2015 and April, 2016. Port Harcourt is situated in the Niger Delta region of Nigeria. It has a tropical humid climate with distinct wet and dry seasons. It is characterized by high humidity (80%) and moderately high temperature between 25 and 30^{0}C. The area is also characterized by heavy rainfall, with total annual rainfall ranging from 2000 to 2500mm, occurring mostly in the months of June through September. Geographically, Port Harcourt is found in latitude 04^0 47'30" N and longitude 06^0 59' 30" E [12].

2.2 Experimental Design and Treatment Applications

A soil surface, 4.7 x 2.7m on the field was divided into three plots, each 0.9 x 2.7m, with an alley of 1m between plots. Each plot was further subdivided into ten smaller units or cells of size 0.3 x 0.3m, with a spacing of 0.3m between cells. Shallow drains were constructed in the spacing between cells and between plots with a view to preventing treatment from one cell or plot flowing into the other, either by surface runoff or interflow.

The nutrient used for bioremediation were NPK (15:15:15) fertilizer, spent mushroom substrate (SMS), and pig slurry (PS). The treatments consisted of 150g (16.667t/ha) of NPK, SMS, and PS; 200g (22.222 t/ha) of NPK, SM, and PS; 250g (27.778 t/ha) of NPK, SMS and PS. There was also a control that represented the natural condition of the soil and so had no treatment. The treatment combinations were laid out in a randomized complete block design, with all treatments appearing in each plot, replicated thrice. There were therefore ten treatments in each plot, giving a total of thirty experimental cells. Since the period of investigation was the dry season (November to April), irrigation water, at a rate of 0.002 m^3/s and at an interval of 4 days,, was applied uniformly to each plot, using watering can with roses similar to overhead irrigation method. 0.4 litres of crude-oil (Bonny light) from Shell Petroleum Development Company, Port Harcourt, Nigeria, was sprinkled upon each cell, except the control. The cells were left undisturbed for a week for proper infiltration of the crude-oil, after which the treatments were applied. All the cells were then tilled with hand trowel and homogenized twice a week. This was done with a view to ensuring proper aeration and mixing of nutrient and microbe with the contaminated soil.

2.3 Planting

After eight weeks of remediation, three seeds of maize (farz 27) were planted in the centre of each cell, but later thinned to two plants after germination. The seeds were obtained from the Agricultural Development Programme (ADP), Port Harcourt, Nigeria.

2.4Soil Sample Collection And Analysis

Composite soil samples, between 0-30cm were collected from the cells using soil auger, from different periods i.e. before contamination with crude-oil, one week after contamination, four weeks after remediation (4 WAR), and eight week after remediation (8 WAR). These samples were placed in labeled polythene bags and taken to the laboratory for physico-chemical and microbial analysis. The parameters analysed were pH, electrical conductivity (EC), total hydrocarbon content (THC), and total nitrogen (TN). Others were available phosphorus (P), available potassium (K), and hydrocarbon utilizing bacterial (HUB). pH was determined with Hanna pH meter H 122110, while EC was measured with Hanna EC 214 conductivity meter K 015572. The other parameters were determined by adopting the procedures outlined by [13,14,15, 16].

The analysis of variance (ANOVA) was used to compare the variability in yield due to the application of the different levels of nutrients. This is due to the fact that yield data were the main index used to evaluate the extent of biodegradation by the nutrients.

II. RESULTS ADD DISCUSSION

Table 1 presents the chemical and microbial properties of PS and SMS. Thus, all the substrates used, including NPK (15:15:15) fertilizer, contain N and P which are known as the most important nutrients needed by hydrocarbon – utilizing bacteria to carry out effective and efficient biodegradative activities of xenobiotics in the soil environment [17].

Table 1: Chemical and microbial properties of pig slurry (PS) and spent mushroom substrate (SMS)

Parameters	PS	SMS
pH	7.20	6.80
Moisture content(%)	19.10	17.50
Electrical conductivity(µs/cm)	26.70	24.28
Organic matter (%)	48.50	54.20
Organic carbon (%)	27.70	32.03
Total nitrogen (%)	2.50	1.24
Available phosphorus(%)	0.83	0.15
Available calcium(%)	0.20	0.10
Available magnesium (%)	0.60	0.06
Available potassium (%)	1.50	0.14
THB (cfu/g)x10^6	0.20	0.27
HUB(cfu/g)x 10^3	1.00	0.46

Table 2 shows that the pH of the soil increased by a maximum of 10.7% one week after contamination with crude-oil. However, this increase was not sufficient to alter the acidic nature of the soil.

Table 2. Physico-Chemical And Microbial Properties Of The Soil (0 – 30cm Depth) Before, And One Week After Crude-Oil Contamination

Parameters	Before	Contamination with crude-oil, one week after (but without treatment)		
		Cells for		
		NPK	PS	SMS
pH	5.31	5.87	5.87	5.88
Electrical conductivity(µs/cm)	30.86	68.53	67.94	68.55
Moisture content (%)	20.10	15.3	16.00	15.86
Total organic carbon (%)	0.24	0.4	0.39	0.40
Total nitrogen(%)	0.22	0.16	0.16	0.15
Total hydrocarbon content (mg/kg)	83.51	12568.42	12580.17	12545.88
Available phosphorus(%)	0.16	0.17	0.20	0.20
Available potassium (%)	0.12	0.08	0.08	0.08
HUB(cfu/g) x 10^4	3.07	25.73	25.66	25.71

Although the contamination was a one-off exercise, the result is in consonance with some other research findings that indicated increase in pH as the level of contamination increased [18; 19; 20]. It has however been observed that after two weeks of pollution by different levels of crude-oil, the soil pH decreased [21]. This is contrary to the assertion that crude-oil contamination could potentially alkalinize marsh soil, thus adversely affecting soil fertility and physical properties, resulting in the deterioration of the marshes[18]. It has also been observed that the optimum pH value for the growth of many plants is between 6.5 and 7.5[22].

Table 2 further indicates an increase in electrical conductivity (EC) of the soil, one week after contaminating with crude-oil. EC is a measure of ionic concentration in soils and is therefore related to dissolved solutions [22]. Dissolved salts in water exert osmotic forces on the water. Since EC value and salt concentration are linearly related, and, osmotic forces increase linearly with salt concentration, it implies that a linear relationship also exists between the osmotic forces in the soil solution and its EC value [22]. In addition to osmotic forces, there are matric forces which also hold water in the soil. Thus, these forces must be overcome for plants to remove water from the soil. A high EC value, resulting from the crude-oil contamination, is therefore an indication that less water will be available for plant use. Total organic carbon (TOC) increased slightly in the soil one week after pollution with crude-oil, as shown in Table 2. This same observation has also been made [21; 24]. The increase was attributed to microbial mineralization of the crude oil. The increase has also been attributed not only to the high amount of carbon in the oil but also to the slow decomposition rate of the amendment by soil organisms, as contamination of the soil with crude-oil might have resulted in poor soil aeration [25]. Total nitrogen (TN) decreased in the soil one week after crude-oil pollution. Some other researchers have made similar observation [1; 20; 26]. Bacterial population was utilizing the available nitrogen for hydrocarbon degradation.

Table 2 also shows that there was an astronomical increase in THC of the soil one week after contamination with crude-oil. The chemical composition of crude-oil is predominantly a complex mixture of both low and high molecular weight hydrocarbons. Thus, a soil polluted with crude oil would, naturally, have an over enrichment of total hydrocarbon, depending, of course, on the amount of crude-oil pollutant. The increase in THC is in conformity with the findings of other researchers [1; 26]. The increase in hydrocarbon utilizing bacteria (HUB) is also attributed to the addition of crude-oil.

Table 3 indicates that apart from the control, all the treatments after eight weeks of remediation increased the pH of the soil when compared to the first week after contamination (Table 2)

. **Table 3. Physico-chemical and microbial properties of the soil 4 and 8 weeks after remediation.**

Nutrient variety	Nutrient Amount (t/ha)	Parameters															
		pH		EC (µs/cm)		THC (mg/kg)		TOC (%)		TN (%)		Avail. P (%)		Avail. K (%)		HUB (cfu/g) x 10^4	
		WAR		WAR		WAR		WAR		WAR		WAR		WAR		WAR	
		4	8	4	8	4	8	4	8	4	8	4	8	4	8	4	8
Control		5.28	5.58	37.10	34.00	83.53	83.58	0.23	0.24	0.11	0.16	0.11	0.09	0.08	0.08	3.09	3.08
NPK	16.667	5.57	6.00	83.72	82.51	2973.94	2722.34	0.28	0.26	0.09	0.07	0.10	0.09	0.06	0.04	120.50	74.62
PS		5.61	6.31	72.58	73.13	2290.94	1581.26	0.34	0.30	0.06	0.06	0.14	0.12	0.06	0.06	198.52	136.37
SMS		5.65	6.07	72.46	72.41	2505.36	2101.77	0.31	0.28	0.05	0.04	0.12	0.11	0.05	0.04	163.54	105.49
Control		5.28	5.6	38.24	32.78	83.53	83.55	0.24	0.24	0.11	0.11	0.10	0.11	0.07	0.06	3.08	3.10
NPK	22.222	5.68	6.06	83.80	84.31	2708.16	1940.17	0.31	0.28	0.12	0.14	0.09	0.07	0.06	0.05	186.15	95.03
PS		5.71	6.29	73.78	74.06	2213.8	1285.9	0.36	0.26	0.10	0.13	0.10	0.07	0.05	0.06	279.83	144.91
SMS		5.76	6.07	73.55	73.82	2497.41	1591.61	0.32	0.28	0.10	0.11	0.10	0.08	0.06	0.04	201.56	133.72
Control		5.30	5.57	38.24	35.21	83.51	83.55	0.24	0.24	0.17	0.11	0.11	0.10	0.07	0.07	3.08	3.08
NPK	27.778	5.68	6.03	88.24	88.64	2495.53	1600.36	0.25	0.23	0.13	0.16	0.10	0.06	0.05	0.04	198.26	100.37
PS		5.63	6.20	74.48	78.31	2089.35	1109.81	0.24	0.23	0.14	0.16	0.08	0.05	0.04	0.04	333.56	173.68
SMS		5.66	6.15	74.01	76.56	2332.93	1426.53	0.25	0.22	0.13	0.15	0.09	0.07	0.04	0.05	291.33	157.66

WAR=Weeks after remediation

A similar trend has been observed with the assertion that the increase in pH may favour degradation by microorganisms [21; 27]. The polluted soil remediated with 22.222 t/ha of PS produced the highest pH during the remediation period. It has however been observed that the pH decreased after six weeks of remediation [1]. There was also a general increase in EC by all the treatments up to eight weeks after remediation. A related study however indicated a general decline in EC between 15 and 60 days of remediation [28]. Increase in EC during remediation has been attributed to the soluble salt-content in the soil arising from the introduction of inorganic fertilizer [1;13]. Table 3 further indicates that the highest EC level resulted from the remediation by 27.778 t/ha of NPK, while the highest reduction in THC after eight weeks of remediation was brought about by 27.778 t/ha of PS. Although at 27.778 t/ha of nutrient addition, the levels of THC reduction by NPK, PS and SMS were 87.3, 91.2, and 88.6% respectively, the difference was not significant at 5% level.

At the end of the eighth week after remediation, application of 16.667 t/ha and 27.778 t/ha of NPK reduced TOC by 35 and 42.5% respectively when compared with the soil one week after pollution, while the same quantities of PS reduced TOC by 23.1 and 41% respectively. For SMS, the same quantities reduced TOC by 30 and 45% respectively. Thus, there was a general reduction in TOC with increase in nutrient quantity. This trend has been associated to the fact that bacteria need a source of carbon for cell synthesis in the course of their metabolism during the degradation process and so utilized the organic carbon for their metabolism, leading to a decline in organic carbon [1]. Total nitrogen (TN) did not show a consistent trend. Application of 16.667 t/ha of nutrients reduced TN when compared with the control, eight weeks after remediation. This is due, in part, to the reduction in HUB during the same period. However, utilization of available N by bacterial population for hydrocarbon degradation will diminish available N with time [29].

Application of 16.667 t/ha of NPK reduced available P by 47.1% while 27.778 t/ha reduced the level by 64.7%. For PS, there was also a general reduction of available P with increased quantity of PS. A similar trend was observed for SMS. Although the pollution of the soil with crude- oil was a one-off exercise in this study, some other researchers have reported decreased levels of available P with increase in levels of crude-oil pollution [24; 30; 31]. HUB increased as remediation progressed, with the highest increase occurring four weeks after remediation, and with PS amended soil producing the largest (333.58 cfu/g x10^4). As the treatments were applied only once at the beginning of the remediation period, less HUB would be available after a certain interval as the nutrients are depleted. It has been posited that with increasing time and availability of less nutrients, bacteria growth and oil degradation would decrease [17;32;33].

The growth and yield performance of maize are presented in Table 4. The table shows that one week after planting (1 WAP), the control which was unpolluted and irrigated but without the addition of nutrients recorded the highest germination rate (90.29%), while the highest germination rate from the pollution but remediated soils came from SMS (68.82%) which was supplemented with nutrient amount of 27.778 t/ha.

Table 4. Mean Growth And Yield Parameters Of Maize.

Nutrient variety	Nutrient amount (t/ha)	Seedling emergence(%)	Plant height(cm)		Leaf area(cm^2)		Grain yield(t/ha)
		1WAP	4WAP	14WAP	4WAP	14WAP	
Control	16.667	90.26	39.73	140.31	308.52	496.84	2.56
NPK		41.71	21.28	66.43	107.74	116.51	0.98
PS		46.05	21.84	68.38	109.38	132.36	1.10
SMS		46.05	22.36	66.85	107.91	132.68	1.06
Control	22.222	89.98	40.17	140.28	310.11	500.10	2.58
NPK		63.14	21.64	67.91	111.63	143.72	0.98
PS		67.51	23.85	70.14	114.37	151.81	1.15
SMS		64.28	23.85	68.83	111.94	148.33	1.18
Control	27.778	90.29	40.36	140.28	309.86	498.67	2.58
NPK		68.30	28.38	83.65	113.51	210.31	1.11
PS		68.04	30.13	97.32	118.16	280.72	1.20
SMS		68.82	28.81	95.17	114.08	233.16	1.17

WAP = Weeks after planting.

This observation has been supported with the fact that crude-oil application delay and decrease the rate of germination [20]. For pant height, the control also produced the highest height (140.28cm) both at 4WAP and 14WAP. However, the highest height from the polluted and remediated soils was obtained from 27.778 t/ha of PS (97.32cm), 14 WAP. The same trend was observed in lead area. The growth performance of maize on the soil remediation by PS may be attributable to the nutrient's high content of N, P, and K. The highest grain yield of 2.58 t/ha was also obtained from the control, while the highest yield from the polluted but remediated soils was 1.20 t/ha from 27.778 t/ha of PS. This indicates about 53.5% reduction in grain yield between the unpolluted and polluted but remediated soils. The difference in yield between the control and polluted but remediated soils was significant at the 5% level, while there was no significant difference in yield between the remediated soils. This shows that although the polluted soils were remediated, albeit partially, crop performance was still negatively affected.

III. CONCLUSION

The three substrates, NPK, PS, and SMS used for the remediation of the crude-oil polluted soils reduced THC in the following order: PS > SMS > NPK. Thus, the performance of maize planted in the soil remediated by these nutrients generally followed the same order. On the whole, however, there was 53.5% reduction in maize yield between the unpolluted and untreated, and polluted but remediated soils mainly due to the non-restoration of the polluted soil back to its original status.

REFERENCES

[1]. M. J. Ayotamuno, R. B. Kogbara, S. O. T. Ogaji, and S.D. Probert. Bioremediation of a crude-oil polluted agricultural soil at Port Harcourt, Nigeria, Applied Energy, 83 (11), 2006, 1249-1257.

[2]. A. I. Koh. Biodegradation of Bonny light crude oil in soil microcosm by some bacteria strains isolated from crude oil flow stations saver pits in Nigeria, 2003 104 – 108.

[3]. A O. Nwadingwe and E.G. Onyeidu. Bioremediation of crude – oil polluted soil using bacterial and poultry manure monitored through soya bean productivity, Pol. J. Environs Stud. 2(1), 2012.

[4]. R. I. Aboribo. Oil politics and the Niger Delta Development Commission; the tussle for control and domination, Afr. J. Environ., Stud., 2, 2001, 168-175.

[5]. O. M. Adedokun, and A. E. Ataga. Effect of crude oil and oil products on growth of some edible mushroom, Journal of Applied Science and environmental Management, 10(2), 2006, 91-93.

[6]. O. E. Essien, and I. A. John. Impact of crude-oil spillage pollution and chemical remediation on agricultural soil properties and crop growth, J. Appl. Sci. Environ. Manage, 14(4), 2010, 147-154.

[7]. J. Wyszkowska, and J. Kuchearski, Biochemical properties of soil contaminated by petrol, Polish J. of Environ. Stud., 9(6), 2000, 476-485.

[8]. S. E. Agrari, C. N. Owabor, And R. Yusuf. Bioremediation of soil artificially contaminated with petroleum hydrocarbon oil mixtures: evaluation of the use of animal manure and chemical fertilizer, Bioremediation Journal, 14(4) 2010, 189-195.

[9]. N. U. Udeh, I. L. Nwaogazie, and Y Momoh, bio-remediation of a crude oil contaminated soil using water hyacinth (Eichhornia crassipes), Advances in Applied Science Research, 4(2), 2013, 362-369.

[10]. R. Margesin, and F. Schinne. Bioremediation (natural attenuation and biostimulation) of diesel – oil contaminated soil in an alpine glacis skilling area, Applied and environmental Microbiology 67 (7), 2001, 3127-3133.

[11]. R. C. Eneje, C. Nwagbara, and E.G. Uwumarongie – Ilori. Amelioration of chemical properties of crude oil contaminated soil using compost from calapoigoniummucunoides and poultry manure, International Research Journal of Agricultural Science and Soil Science, 2(6), 2012, 246-251.
[12]. S. Ors, U. Sahin and F. M. Kiziloglu. Yield, quality and irrigation water use of drip-irrigated silage maize with different irrigation techniques, Pak. J. A. Agri. Sci., 52(3), 2015, 595-607.
[13]. C.T.I. Odu, O.F. Esuruoso, L. C. Nwoboshi and J.A. Ogunwale. Environmental study of the Nigeria Agip Oil Company Operational Areas, Proc. Soil and fresh water vegetation Conf. Milan (Italy), 1985.
[14]. A Walkley and I. A. Black. Determination of organic carbon on soil, Soil Science, 37(1), 1934, 29-38.
[15]. J. M. bremmer, and C.S. Mulvaney. Soil total nitrogen in: methods of soil analysis, part 2 (Page et al, 2nd ed. Agron Mono 9 Assa. Ssa WI. 1982).
[16]. W.F. Harrigen, and M.E. McCane. Laboratory methods in food and dairy microbiology (8th Edition, Academic Press, London, 1990).
[17]. O. P. Abioye, P. Agamuthu, and A.R. Abdul Aziz. Biodegradation of used motor oil in soil using organic waste amendments, Biotechnology Research International, 2012, 1-8.
[18]. Y. Wang, J. Gengi Q. Lin, X Lui, X. Wang, and G. Wang. Effect of crude oil contamination on soil physical and chemical properties in Momoge Wetland of China, Chinese Geographical Science , 23(6), 2013,708-715.
[19]. B. U. Uzoho, N.N. OTI, and E. U. Onweremadu. Effect of crude oil pollution on maize growth and soil properties in Ihiagwa, Imo State, Nigeria, International Journal of Agriculture and Rural Development, 5(1), 2004.
[20]. A. Amadi, A.A. Dickson, and G.O. Maate. Remediation of oil pollution soils: 1. Effect of organic and inorganic nutrient supplements on the performance of maize (Zea may L), Water, Air and Soil Pollution, 66, (1993), 59-76.
[21]. N.A. Obasi, E. Eze, D. I. Anyanwu, and U.C. Okorie. Effects of organic manures on the physicochemical properties of crude oil polluted soils, African Journal of Biochemistry Research, 7(6), 2013, 67-75.
[22]. I. L. R. Oyem, and I.L. Oyem. Effect of crude oil spillage on soil physico-chemical properties in Ugborodo Community, International Journal of Modern Engineering Research, 3(6), 2013, 3336-3342.
[23]. L. K. Smedema, and D.W. Rycroft, Land drainage: planning and design of agricultural drainage systems (Batsford Academic and Educational Ltd, London, 1983).
[24]. J.C. Okolo, E.N. Amadi, and C.T.I Odu, Effects of soil treatment containing poultry manure on crude oil degradation in a sandy loam soil, Applied Biology and Environmental Research, 3(1), 2005, 47-53.
[25]. W. M. Shukry, G.H.S. AL-Hawas, R.M.S. Al-Moaikal, and M.A. El-Bendary, Effect of petroleum crude oil on mineral nutrient elements, soil properties and bacterial biomass of the rhizospher of Jojoba, British Journal of Environment & climate change, 3(1), 2013, 103-118.
[26]. C.C. Anuyadike, I. Akunne, B.O. Ugwuishiwu, G.N. Ajah, and V.I. Ogwo, Remediation of crude oil-polluted soil with lime, I0SR Journal of Engineering (10SRJEN), 3(10), 2013, 05-07.
[27]. U.J.J. Ijah, H. Safiyanu, and O,P, Abioye, comparative study of biodegradation of crude oil in soil amended with chicken droppings and NPK fertilizer. Science World Journal, 3(2), 2008, 63-67.
[28]. F.C. Ibe, B.O. Ibe, C.B.C IKPA, and M.C. Eneldoh, Remediation of mild crude oil polluted fresh water wet land with organic and inorganic fertilizers, International letters of National Sciences, 54, 2016, 75-84.
[29]. M. Chorom, H.S. Shaifi, and H. Motamedi, Bioremediation of a crude oil – polluted soil by application of fertilizers, Iran J. Environ. Health Sci. Eng., 7(4), 2010, 319-326.
[30]. M. O. Onuh, D.K. Madukwe, and G.U. Ohia, Effects of poultry manure and cow dung on the physical and chemical properties of crude oil polluted soil, Science World Journal, 3(2), 2008, 45-50.
[31]. N. O. Isirimah, K. Zuofa, and P. Loganathan, Effect of crude oil on maize performance and soil chemical properties in the humid zone of Nigeria, J. Discov. Innov. 1(3), 1989, 85-98.
[32]. O. A. T. Ebuehi, I.B. Abibo, P.D. Shekwolo, K.I. Sigismund, A. Adoki, and I.C. Okoro, Remediation of crude oil contaminated soil by enhanced natural attenuation technique, Journal of Applied Sciences and Environmental Management, 9(1), 2005, 103-106.
[33]. M. Schaefer, and F. Juliane, The influence of earthworms and organic additives on the biodegradation of oil contaminated soil, Applied Soil Ecology, 35(2), 2007, 53-62

*1Fubara-Manue. "Performance of Irrigated Maize in A Crude-Oil Polluted Soil Remediated By Three Nutrients In Nigeria's Niger Delta." American Journal of Engineering Research (AJER), vol. 06, no. 12, 2017, pp. 180-185.