pilot farms – SC "Radyans'ka zemlya"", Belozersky district, Kherson region, in the Ingulets irrigation system. The program included studies of physical-chemical, chemical and physical properties of soil and irrigation water quality. In the post-irrigation period (over 15 years) the gradual regeneration of the properties of the long irrigated soil occurs. The processes of desalinization (reduction of toxic salts content to 0.04-0.08 %), dealkalinization (decrease of the exchangeable sodium and potassium concentration to 2.5-2.9 %), decompaction are developed. In the soil the amount of agronomically useful structure aggregates (10 %) was increased. The content of lumpy fraction (8-9 %) was decreased.
On the basis of the results of the integrated soil assessment this soil is recommended for introduction in irrigated agriculture.

Keywords: *irrigation recommencement, soil, found out from irrigation, irrigation water, irrigation, soil-ameliorative properties, transformation.*

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IMPACT OF DIFFERENT SOIL AMENDMENTS ON CRUDE OIL POLLUTED SOIL AND PERFORMANCE OF MAIZE

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Effects of different soil amendments on crude oil polluted soil and performance of maize was carried out in Egbema, Imo State. The experiment was laid out in a complete randomized design in three replications in pots. Eighteen pots were used in this study, with 9kg soil packed in each pot. The soil in each of the pots was polluted with 22.5g (5t/ha) of crude oil, simulating the spill in the field except in control (Zero pollution). There were six treatments consisting of NPK 20:10:10, Crushed limestone ($CaCO_3$), Cured cow dung (CD), Cured poultry manure (PM), each applied at the same rate of 13.5g (3t/ha) except in control (Ct) and unamended polluted (UP). Percentage organic carbon was determined three times after amendment. Two maize seeds (Oba II) were planted in each pot. Seed emergence, plant height, time of tasseling, time of silking and yield were recorded in this study. The soil was loamy sand; percentage porosity was moderately high across the pots. The texture was not affected by crude oil pollution; however, it influenced the chemical properties of the soil. Percentage organic carbon was high after pollution, pH was reduced and C/N ratio widened. LSD at 5% probability, showed that crude oil pollution affects basic cations in the soil especially magnesium. The amendment however, reduced the percentage organic carbon, narrowed the C/N ratio, and increased the basic cations and the pH. The performance of maize crop in this study showed the positive impact of the amendment materials used on crude oil-polluted soil when compared with control and unamended polluted pots. NPK-treatment showed a high level of amendment than other treatments; with yield 47t/ha for NPK, 24t/ha for Limestone, 20t/ha for Cow dung, 29t/ha for Poultry manure, then 20t/ha and 18t/ha for Control and Unamended polluted.

Keywords: *Impact, soil amendments, crude oil pollution, performance, maize.*

1. Introduction

Oil pollution is the introduction of crude or petroleum products to the environment, by the activities of man causing hazards to living resources by interfering with their legitimate use of the environment [1]. Crude oil pollution is a release of liquid petroleum hydrocarbon into the environment anthropogenically [2]. Crude oil has been commercially explored since the middle of the 19th century and used for many decades for illumination; on a smaller scale, as lubricant [3]. The invention of the internal combustion engine and its vast adoption in all transport forms enlarged the employment of this natural resource, thus increasing its demand production, transport, stockpiling, and distribution, as well as the raw oil and its by-products. All these activities involve pollution risks that can be minimized, but not totally eliminated, causing several problems to the environment.

Oil pollution in our environment has a serious hazard to human health [4]; it can pollute ground water which limits its usefulness to agricultural productivity of the soil [5]. Crude oil-polluted soils may remain unsuitable for plant growth for months or years depending on the degree of pollution. Natural rehabilitation of such soils may take some time to accomplish because of high demand on land [6]. In Nigeria, quite a substantial amount of crude oil is spilled annually. Between 1960 and 2003, over forty million barrels of crude oil were discharged into the environment [7]. The most noticeable sources of pollution are releases from manufacturing and refining installations, pipe line damages and vandalization, oil-tanker spills and accidents during transportation of the oil. Crude oil spills result in an imbalance in the carbon–nitrogen ratio at the spill site, because crude-oil is essentially a mixture of carbon and hydrogen. This causes a nitrogen deficiency in an oil-soaked soil, which retards the growth of bacteria and the utilization of carbon sources [8]. One approach to restoring contaminated soils is to make use of substances able to degrade the crude oil in a remediation process.

A combination of treatments, consisting of the application of fertilizers and oxygen exposure on remediation of a crude oil-polluted agricultural soil was evaluated by [9]. They found that the quantities of fertilizer (NPK) (i.e. 4.7 to 12.5 ton/ha), moisture content between 14 % and 19 % during the wet season and a tillage rate between 2 and 5 times a week, are necessary for an effective remediation. Organic manure has over time been used to improve soil fertility; [10] discovered the efficiency of organic manure in promoting plant growth in crude oil polluted soil. Ademole and Aboyeji [11] discovered in their experiment that maize planted in soil amended with poultry compost manure and in soil devoid of spent engine oil had the highest plant height than that planted in spent engine oil-polluted soil.

The objective of this study therefore is to determine the effect of different amendment materials, on the physical and chemical properties of crude oil-polluted soil and the performance and yield of maize in the amended polluted soil.

2. Materials and methods

2.1. Study Site

Egbema is an oil producing community in Imo state, South Eastern Nigeria which lies between latitude 5°18'N and 5°31'N; and between longitude 6°56'E and 6°95'E. The area lies within the humid tropics with annual rainfall of 2000-2500 mm; annual temperature range of 25-30 °C. The vegetation falls within the tropical rainforest zone.The geo-formation of the area is mainly sandy Benin formation, characterized by Quaternary alluvium, meander belt, wooded back swamp as well as fresh water swamps. It also lies in a low plain of rainfall; this consequently ensures vertical and horizontal migration of fishes. Majority of them are farmers; they produces oil palm products, yam, cassava, pineapple, maize and plaintain. The grassland which spans several kilometers offers good habitation for rearing of livestock such as goat, sheep, rabbit, glasscutters etc. they are also blessed with wide palm trees for wine tapping.

2.2. Field work

The selected site was devoid of slopes, and 60 meters away from the tarred road.

Random soil sample technique was used to collect soil samples. Five samples (0-15 cm) were collected randomly using auger. Soils were also collected with three core-samplers in the field for the determination of bulk density. The soil samples were bulked, bagged and taken to the plant house in FUTO, where it was air-dried and sieved with 2 mm sieve, subsequently, a sample and soils in three core samples were taken to the laboratory for analysis, the rest was kept ready for packing.

2.3. Experimental design and treatment

Six treatments: NPK 20:10:10, crushed limestone, poultry manure, cow dung, control and unamended polluted were employed in this study. These treatments were replicated three times in a Completely Randomised Design, giving a total of eighteen experimental units.

2.4. Procedure

Soil packing was done in a plant house. Eighteen (18) perforated pots of volume 8064cm^3 (8 litres) were brought. The mass of the soil to be packed in each of the pots was determined using the insitu-bulk density of the study site which was 1.08 g/cm^3.

Therefore, using a formula: BD = M/V; M = 1.08 g/cm^3 × 8064 cm^3= 9 kg (approximately)

9 kg of soil was weighed with a scale and packed in each of the experimental pots.

Five tonnes per hectare (5 t/ha) of crude oil was used in the experiment. Crude oil in the soil as small as 2 t/ha is capable of affecting crop yield negatively [12].

Also, [13] stated that 2000000 kg of soil in the first 15 cm depth of soil is in one (1) hectare of land.Therefore, 2000000 kg → 5000 kg; 9 kg → 0.0225 kg = 22.5 g.

Each experimental pot except Control (Ct) and its replicates were polluted with 22.5 g of crude oil. 22.5 g of crude oil was weighed using a small electronic scale and spilled on the soil; this process was repeated on all the pots except Control (Ct) and its replicates. They were left undisturbed for fourteen (14) days before amendment to infiltrate the soil; which reflects what happens in the oil-spill site.On the fourteenth day after pollution, soil samples were collected from each pot and taken to the laboratory for analysis. The pots were watered lightly after the collection of soil samples. On the fifteenth day after pollution, the soil was amended with three tonnes per hectare (3 t/ha) of each amendment materials.

For, 2000000 kg = 3000 kg; 9 kg = 0.0135 kg= 13.5 g.

13.5 g NPK per pot in three replicates, 13.5 g of PM per pot in three replicates, same as limestone, and cow dung, was used except in Control (Ct) and unamended polluted (UP) and their replicates.Twelve clean sack-bags were used in the application process where each sack-bag was used for each pot to avoid contamination. A sack-bag was spread on the floor and emptied a pot of crude oil-polluted soil on it; 13.5 g of the amendment materials were weighed separately with an electronic scale, application was by spreading method and mixed properly with a hand trowel before packing it back into the pot. This was done to each treatment pot and its replicates except Control (Ct) and Unamended Polluted (UP).The eighteen pots were watered three (3) hours after amendment and were left to incubate for sixty (60) days. Meanwhile I was watering the pots every four (4) days throughout the incubation period. However, soil samples were collected from each of the pots on the seventh (7th), twenty first (21^{st}), thirty fifth (35^{th}) and forty ninth (49^{th}) day after amendment, and taken to the laboratory for analysis.

2.5. Planting

Planting of maize seeds (Oba II super) was done seventy five days (75) after pollution; two seeds per pot. Plant parameters measured were percentage emergence, plant height, time of tasseling, time of silking and yield (t/ha).

2.6. Laboratory analysis

Bulk density was determined using core sample method [14] as modified by Arshad [15]; the difference between the wet sample and oven-dried weight gave the moisture percentage by weight. Particle size was determined using mechanical analysis by Bouyoucos hydrometer method [16]. Soil pH (1:2.5 ratio) in water and KCl was determined using pH-meter. Exchangeable acidity (Al^{3+} and H^{+}) was extracted as described by [17]. Exchangeable basic cations were extracted with ammonium acetate; Mg and Ca were measured by ethylene diaminetetracetic acid titration while K and Na were estimated by flame photometer method. The organic carbon content of the soil was determined by Walkley and Black digestion method as modified by Nelson and Sommer [18]. The Cation Exchange Capacity of the soil was determined by summing up exchangeable bases in $cmolkg^{-1}$. Total Nitrogen was determined by macro-kjedahl digestion method as modified by Dahnke and Johnson [19]. Carbon – Nitrogen ration was determined by dividing percentage organic carbon by total nitrogen. Available phosphorus was determined using Bray II method [20]. All the laboratory analysis was done soil science lab at Federal college of land resource and Technology, Owerri Nigeria.

2.7. Data Analysis

The data were analysed statistically using GenStatDiscoverey Edition 4, and means were compared using Least Significant Different (LSD) at 0.05 probability level.

3. Results and discussion

3.1. Properties of soil before pollution

Table 1 shows the physical properties of the soil in Egbema. The soil was loamy sand, having 87 % sand, 12 % clay and 1 % silt; sandiness of the soil could be attributed to a combination of influences from parent materials, climate, land use type and land use history [12].The bulk density was 1.08 g/cm^3 which is ideal for plant growth [15]. The percentage moisture content showed 14 % which is also moderate for top soils [15].

Table 1

Physical properties of soil before pollution

Studied soil	SAND, %	SILT, %	CLAY, %	BD, g/cm^3	MC, %
Egbema	**87.07**	**1.33**	**11.60**	**1.08**	**13.59**

Keys: BD = bulk density, MC = moisture content.

Table 2 shows the chemical properties of the studied soil. The pH was moderately acidic having a pH value of 5.19 [21]. Exchangeable cations are moderate, having moderate levels of Ca^{2+}, Mg^{2+}, K^+ and Na^+. C/N ratio was narrow having a value of 4.40; available Phoshorus was moderate having a value of 10.37 [22].

Table 2

Chemical properties of soil before pollution

Studied soil	pH (H_20)	pH (KCl)	Al^{+3}	H^+	OC (%)	TN (%)	Ca^{2+} (cmol/kg)	Mg^{2+} (cmol/kg)	K^+ (cmol/kg)	Na^+ (cmol/kg)	C/N	Av.P (ppm)
Egbema	5.19	4.31	0.90	0.17	0.62	0.14	3.23	2.85	0.33	0.43	4.40	10.37

Keys: Ca = Calcium; Mg = Magnesium; K = Potassium; Na = Sodium; Al = Aluminum; H = Hydrogen; OC = organic carbon; Av.P = Available Phosphorus; C/N = Carbon and Nitrogen Ratio; TN – total Nitrogen.

3.2. Changes in soil properties after pollution

The soil was coarse across the experimental pots with sand showing a range of 85 % to 87 %, silt showing a range of 2 % to 3 %, and clay showing a range of 11 % to 13 %, although, the bulk density across the polluted pots are a little bit higher than the control, there was no significant effect ($p \le 0.05$) of crude oil pollution on physical properties of the studied soil (see Table 3).

Table 3

Physical properties of soil after pollution

S/N	TREATMENT	SAND, %	SILT, %	CLAY, %	BD, g/cm^3	MC, %	T.POROSITY, %
1	NPK	87.07	2.00	10.93	1.36	13.81	48.53
2	$CaCO_3$	85.07	2.67	12.27	1.18	14.01	55.60
3	CD	85.73	1.67	12.60	1.17	10.79	55.87
4	PM	85.73	2.00	12.27	1.37	12.75	48.20
5	Ct	87.07	1.33	11.60	1.08	13.59	48.53
6	UP	87.40	1.67	10.93	1.30	13.63	50.93
	LSD (0.05)	13.91	1.109	0.839	0.132	3.68	4.26
	Sign level	NS	NS	NS	NS	NS	NS

Keys: BD = bulk density; MC = moisture content; T.Porosity = Total porosity; NPK = NPK 20:10:10; $CaCO_3$ = crushed limestone; CD = cured cow dung; PM = cured poultry manure; Ct = control; UP = unamended polluted; NS = Not significant.

Table 4, showed a chemical properties of the soil after pollution. pH (H_2O) values was within the range of 5.46 to 3.28, the highest value was recorded in the control (Ct), while the lowest value was recorded in unamended polluted (UP). This could be that crude oil reduces soil pH with the formation of toxic acids which is in agreement with [23, 24]. The Percentage Total Nitrogen in the crude oil-polluted soils were far less than Percentage Total Nitrogen in Ct.

The polluted soils having their values within 0.04 % to 0.1 %, and the Ct recorded 0.12 % to 0.16 %. Percentage organic carbon obtained from soils after pollution was three (3) times more than percentage organic carbon in Ct. (Table 4); they recorded within 2 % to 3 %, while Ct, recorded 0.59 % to 0.67 %. The increase of %OC in the polluted pots was attributed to carbon from spilled crude oil. Increase of organic matter is directly proportional to the increase of crude oil addition to the soil [23]. The wide C/N ratios in NPK, $CaCO_3$, CD, PM and UP pots (Table 4) could have led to immobilization of soil nitrates coupled with the environment brought about by the crude oil pollution, accounted for low level of Percentage Total Nitrogen (% TN) in NPK, $CaCO_3$, CD, PM and UP pots. According to Baruah, highly crude oil polluted soils exhibits more organic carbon than less crude oil polluted soils [24].The basic cations were relatively low to moderate across the treatments, with Ct-treatment having higher Ca^{2+} value (3.2 $cmolkg^{-1}$) than NPK, $CaCO_3$, CD, PM and UP (Table 4); this may be due to average to low nutrient endowment of the indigenous soil. The available phosphorus (UP) was relatively moderate across the treatments, however, that of the Ct-treatment recorded high level of P than other treatments, and this is in consonant with the findings of Rowell [14], who explained that crude oil pollution reflects an elevated level of soil organic carbon and available phosphorus. There was a significant effect ($p \leq 0.05$) of crude oil pollution on pH, percentage organic carbon and basic cation (Mg).

Table 4

Chemical properties of soil after pollution

S/N	Treat-ment	pH_{H2O}	pH_{KCl}	Al^{+3}	H^+	OC (%)	TN (%)	Ca^{2+} (cmol/kg)	Mg^{2+} (cmol/kg)	K^+ (cmol/kg)	Na^+ (cmol/kg)	C/N	Av.P (ppm)
1	NPK	4.14	3.97	0.20	0.60	2.82	0.08	2.57	0.86	0.43	0.44	37.4	10.90
2	$CaCO_3$	4.23	3.90	0.47	0.43	2.44	0.06	2.87	0.11	0.42	0.39	45.7	10.23
3	CD	3.99	3.81	0.60	0.27	2.40	0.06	2.73	0.90	0.45	0.47	37.7	10.37
4	PM	4.30	4.13	0.43	0.43	2.17	0.05	3.03	1.61	0.42	0.37	47.8	10.25
5	Ct	5.19	4.31	0.90	0.17	0.62	0.14	3.23	2.85	0.33	0.43	4.40	10.37
6	UP	3.49	3.19	0.47	0.53	2.95	0.08	2.57	1.15	0.24	0.33	41.6	9.10
	LSD (0.05)	0.45	0.39	0.32	0.24	0.50	0.04	0.77	0.59	0.20	0.18	20.4	1.94
	Sign level	**	**	*	*	**	NS	NS	**	NS	NS	*	NS

KEY: Ca = Calcium; Mg = Magnesium; K = Potassium; Na = Sodium; Al = Aluminum; H = Hydrogen; OC = organic carbon; Av.P = Available Phosphorus; C/N = Carbon and Nitrogen Ratio; NPK = NPK 20:10:10; $CaCO_3$ = Crushed limestone; CD = Cured cow dung; PM = Cured poultry manure; Ct = Control; UP = Unamended polluted; NS = Not significant.

3.3. Influence of treatments (amendments) on crude oil polluted soil

The amendments reduced the hydrocarbon hence, organic carbon in the crude oil polluted soils (NPK, $CaCO_3$, CD, PM, UP) as shown in (Table 5), where %OC reading was taken at one week after amendment (1WAA), third week after amendment (3WAA), fifth week after amendment (5WAA) and seventh week after amendment (7WAA); before planting of maize crop (Oba II). At the seventh week after remediation, $CaCO_3$ treatment recorded the least %OC which was approximately 44 % decrease from the level it recorded after pollution (Table 4 and Table 5); NPK treatment showed 51 % decrease; CD treatment showed 38 % and PM treatment recorded 32 %. Ct treatment on the other hand showed 1 % decrease in % OC, while UP showed approximately 7 % decrease. The reduction in %OC seen in UP treatment could be attributed to natural breakdown of hydrocarbon in a crude oil polluted soil that is not subjected to further pollution. Therefore crude oil pollution in this study responded positively to NPK treatment more than $CaCO_3$, CD and PM in that order. The treatments showed highly significant difference at 5% probability after one week of amendment (1-WAA) between PM and Ct; at three weeks after amendment (3-WAA) between PM and Ct; at five weeks after amendment (5-WAA) between PM and Ct; at seven weeks after amendments (7-WAA) between PM and Ct. (Table 5).

Table 5

Levels of percentage organic carbon in soil after amendment

S/N	Treatment	Organic carbon content (%)			
		1-WAA (%)	3-WAA (%)	5-WAA (%)	7-WAA (%)
1	NPK	1.56	1.44	1.42	1.37
2	$CaCO_3$	1.62	1.44	1.41	1.36
3	CD	2.02	1.60	1.55	1.48
4	PM	1.80	1.60	1.51	1.47
5	Ct	0.63	0.60	0.58	0.62
6	UP	2.89	2.80	2.78	2.76
	LSD (0.05)	0.22	0.33	0.33	0.29
	Sign. level	**	**	**	**

KEY: WAA = week after amendment; NPK = NPK 20:10:10; $CaCO_3$ = Crushed limestone, CD =Cured Cowdung; PM = Cured Poultry manure; Ct = Control; UP = untreated polluted; ** = highly significant.

3.4. Response of Maize crop to treatments

Table 6, shows number of emerged maize seeds (Oba II) across the pots after five days of planting, which was also 80 days after pollution. There was emergence across the pots, however, CD and Ct showed complete emergence. There was no significant effect of the treatments at p≤0.05 (Table 6), the total percentage emergence therefore, showed 92% (Table 7).

Table 6

Seed emergenc

Treatments	Emergence (piece)		Emergence (%)
	Mean per pot	Total per treatment	
NPK	3.33	10	
$CaCO_3$	3.67	11	
CD	4.00	12	
PM	3.33	10	
Ct	4.00	12	
UP	3.67	11	
LSD (0.05)	1.11^{NS}	-	
Total	-	66	92

KEY: NPK = NPK 20:10:10; $CaCo_3$ = Crushed limestone; CD = Cured Cowdung; PM = Cured Poultry manure; Ct = Control; UP = untreated polluted.
NB: (66 germinated ÷ 72 expected) × 100 = 92 %

Table 7, shows the height of the maize plant across the treatment pots at 1WAP, 2WAP and 3WAP; the first height parameter was taken seven days after emergence. The tallest plants were obtained from $CaCO_3$ treated soils with height, 4.3 cm at one week after planting (1WAP), while Ct-treatment produced the shortest plants with height, 2.7 cm at 1WAP. At 2WAP, the tallest plants were obtained from CD treated soils with height, 10.50 cm, while UP-treatment produced the shortest plants with height, 8.3 cm. More so, at 3WAP, the tallest plants were obtained from Ct treated soils with height, 19.7 cm, while UP-treatment produced the shortest plants with height, 14 cm. There was significant difference at 5 % probability at one week after planting (1WAP) between NPK and $CaCO_3$; at three weeks after planting (3WAP) between Ct and UP; there was no significant difference between treatment means at two weeks after planting (2WAP).

Table 7

Maize height after planting and yield after harvest

S/N	Treatment	1WAP (cm)	2WAP (cm)	3WAP (cm)	Yield (t/ha)
1	NPK	3.10	10.07	19.33	47
2	$CaCO_3$	4.33	9.67	16.67	24
3	CD	3.87	10.50	19.33	20
4	PM	3.17	9.17	18.50	29
5	Ct	2.67	9.17	19.67	20
6	UP	2.93	8.27	14.00	18
	LCD(0.05)	0.86	2.01	2.94	31^{NS}
	Sign. Level	*	NS	*	

KEY: NPK = NPK 20:10:10; $CaCo_3$ = Crushed limestone; CD = Cured Cowdung; PM = Cured Poultry manure; Ct = Control; UP = untreated polluted; * = Significant, NS = Not significant.

Tasseling appeared first on the ninth week after emergence (68 days) after planting. NPK-treatment showed tasseling in two pots; Ct-treatment showed tasseling in only one pot, same as $CaCO_3$-treatment. The rest of the treatments didn't appear that day. After nine days however, tassels appeared in all NPK-treatment pots; the rest showed tasseling in two pots respectively. Tasseling was completed in all the pots on the twelfth day.

Silking first appeared on the eleventh week after emergence, i.e. eighty two weeks after planting. Ct-treatment showed in one pot, the rest of the treatments did not appear until ninety days after planting, when it was seen across the treatment pots

Harvest was done on the seventeenth week after emergence, i.e. 125 days after planting. The sheaths were removed and the maize cobs (cob + grains) were weighed.

The highest yield of 47 t/ha was obtained from NPK-treatment, while UP-treatment on the other hand gave the lowest yield of 18t/ha, however, the treatment has no significant effect at 5 % probability on the yield.

3.5. Chemical properties of soil after harvest

Table 8, shows the chemical properties of soil after harvest. pH (water) showed an increase from the initial value seen after pollution; unamended polluted (UP) also showed an increase in pH which could be as a result of natural breakdown of crude oil in the soil [25].

Percentage organic carbon decreased drastically across the treatment pots, NPK-treatment having 27 % decrease from the value after pollution; the $CaCO_3$-treatment, CD-treatment, PM-treatment and UP-treatment, having 29 %, 18 %,37 % and 25 % decrease respectively.

Ct-treatment showed little or no decrease in percentage organic carbon. The C/N ratio also narrowed significantly across the treatment pots from the wide values they showed after pollution (Table 4, Table 8). This may have happened due to application of these amendment materials to the crude oil-polluted soils. However, C/N ratio of Ct-treatment widened a little, which may be as result of reduced microbial activities in the Ct-treatment pots [26]. There was significant effect ($p \leq 0.05$) of amendment seen in percentage organic carbon and C/N ratio); this shows that the crude oil-polluted soil responded positively to the application of these amendment materials.

Table 8

Chemical properties of soil after harvest

Treatment	pH (H_2O)	pH (KCl)	Al^{3+}	H^+	OC (%)	Ca^{2+}	Mg^{2+}	K^+	Na^+	C/N	TN (%)	Av.P (ppm)
						cmol/kg						
NPK	5.11	4.45	0.37	0.53	2.05	2.20	2.06	0.51	0.40	12.17	0.18	8.84
$CaCO_3$	5.97	5.10	0.51	0.43	1.73	2.87	1.95	0.27	0.44	16.47	0.11	8.97
CD	5.19	4.68	0.40	0.30	1.98	1.91	1.20	0.33	0.42	11.18	0.18	5.88
PM	5.59	4.69	0.40	0.33	2.09	2.27	2.48	0.50	0.46	10.86	0.19	8.77
Ct	5.01	4.77	0.60	0.26	1.01	3.41	0.71	0.29	0.26	7.25	0.14	9.00
UP	4.96	4.44	0.27	0.43	2.22	2.40	1.22	0.22	0.27	25.34	0.09	7.47
LSD(0.05)	0.51	0.66	0.4	0.37	0.44	0.98	1.04	0.20	0.21	7.07	0.07	2.41
Sign. level	NS	NS	NS	NS	**	NS	*	*	NS	**	*	NS

KEY: Ca = Calcium; Mg = Magnesium; K = Potassium; Na = Sodium; Al = Aluminum; H = Hydrogen; OC = organic carbon; Av.P = Available Phosphorus; C/N = Carbon and Nitrogen Ratio; NPK = NPK 20:10:10; $CaCO_3$ = Crushed limestone; CD = Cured cow dung; PM = Cured poultry manure; Ct = Control; UP = Unamended polluted

4. Conclusions

Based on the result of this study, crude oil pollution is capable of altering the chemical properties of the soil; crude oil pollution increases soil organic carbon. Performance of maize was also affected negatively as in the yield per hectare in unamended polluted. Reclamation of crude oil-polluted soil occurs naturally over time though, without further pollution. Inorganic fertilizer, mainly, NPK 20:10:10 at 3 t/ha is capable of amending crude oil-polluted soil. Cured Poultry manure and Cured Cow dung also showed positive response in amending crude oil-polluted soil, as well as Crushed Limestone. In the performance of maize, NPK 20:10:10 performed better than other amendment materials used in this study; which was revealed in their growth, flowering and yield.

These amendment materials also improved the chemical properties of the crude oil-polluted soil; this was glaring in its pH (water), basic cations, organic carbon and C/N ratio after harvest.

NPK 20:10:10 at 3 t/ha can be used in amending crude oil pollution in so long as there is no further pollution. When NPK 20:10:10 is not available, perhaps due to its cost, poultry manure or cow dung can be used, however, it should be given longer time to achieve results. Finally, pipe line vandalization should be discouraged to avoid crude oil pollution in the environment, lest food production would be forever threatened in the area, furthermore, pipe line should be properly maintained to avoid leakages.

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ДЕЙСТВИЕ РАЗЛИЧНЫХ ПОЧВЕННЫХ МЕЛИОРАНТОВ НА СВОЙСТВА ПОЧВЫ, ЗАГРЯЗНЕННОЙ СЫРОЙ НЕФТЬЮ, И РАЗВИТИЕ КУКУРУЗЫ

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Влияние различных почвенных мелиорантов на почвы, загрязненные сырой нефтью и выращивание кукурузы было изучено в в Егбема, штата Имо в Нигерии. Эксперимент был заложен в сосудах по полностью рендомизированной схеме в трех повторениях. Были использованы 18 сосудов, в которых поместили по 9 кг почвы. Загрязнение (разлив нефти) имитировали, добавив к почве в каждом сосуде 22,5 г (5 т/га) сырой нефти, за исключением контрольного сосуда (нулевое загрязнение). Всего было 6 вариантов опыта: NPK 20:10:10; измельченная известь ($CaCO_3$); твердый навоз коров (CD); твердый птичий помет (PM), которые вносили одинаково по 13,5 г (3 т/га) исключая варианты контроль (Ct) и неисправленное загрязнение (UP). Процентное содержание органического углерода определяли три раза после мелиорации. В каждый сосуд были высажены по два семени кукурузы (Oba II). В опыте контролировали прорастание, высоту растений, время выметывания метелки, фаза вымётывания пестичных столбиков и урожай. Почва – супесчаная, умеренно высокой пористости. Грансостав не подвержен влиянию загрязнения сырой нефтью; но химические свойства почвы оказались затронутыми. Процентное содержание органического углерода после загрязнения быо высоким, pH снизился, а отношение C/N расширилось. LSD при 5% вероятности, показало, что загрязнение сырой нефтью затрагивает состав основных катионов в почве, особенно магния. Мелиорация, однако, вызвала снижение процентного состава органического углерода, сужение отношения C/N и увеличение содержания основных катионов и pH. Характеристика растений кукурузы в этих исследованиях показала положительное влияние мелиорантов, использованных на загрязненной почве по сравнению с контролем и немелиорированной почвой. Вариант с NPK показал более высокий уровень мелиорации чем другие варианты. Урожай был таким – 47 т/га для NPK, 24 т/га для извести, 20 т/га для навоза, 29 т/га для птичьего помета, затем 20 и 18 т/га для контроля и немелиорированного загрязнения.

Ключевые слова*: воздействие, почвенный мелиорант, загрязнение сырой нефтью, характеристика, кукуруза.*

IRON, ZINC, COPPER AND MANGANESE AVAILABILITY IN FOUR CONTRASTING HYDROMORPHIC SOILS OF EGBEMA, SOUTH-EASTERN NIGERIA

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Trace elements are particularly sensitive to surrounding environmental condition which influences their availability and behavior in the ecosystem. The study assessed the availability of four trace elements (Mn, Fe, Cu and Zn) in selected wetland soils of Egbema, Imo State, South-Eastern Nigeria. Six composite soil samples (0-30 cm depth) were collected from the different wetlands (Iyiaba, Omanpe, Orashi and Agbo). Soils were generally acidic (5.27-5.64) with low organic carbon (4.4-7.11 g kg^{-1}) and CEC (2.71-5.79 Cmol+kg^{-1}). Omanpe wetland soil contained significantly ($p<0.05$) higher quantity of Fe (43.97 $mgkg^{-1}$) compared to other soils investigated. Also, significantly ($p<0.05$) higher quantity of Cu (0.56 $mgkg^{-1}$) was recorded in Orashi wetland compared to other investigated soils.

Keywords: *ecosystem, hydromorphic soils, trace element, South-eastern Nigeria*