INCIPIENT SOIL DAMAGE IN AN OIL FIELD NEAR THE KWA IBOE RIVER ESTUARY, SOUTHEASTERN NIGERIA.

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ABSTRACT

Soils from areas highly polluted with hydrocarbons were compared with those from relatively unpolluted areas. The aim was to unravel the relationships between hydrocarbon pollution and soil quality. There was a correlation between polluted soils and some soil properties in the soils. Bulk density was considerably higher in polluted soils were highly acidic. Available phosphorous, organic carbon and cation exchange capacity values indicated better soil quality in relatively unpolluted soils than in soils highly affected by hydrocarbon pollution. It was concluded that incipient soil damage occurs consequent to increasing levels of hydrocarbons in soils. The social implications of soil damage included decreasing agricultural activity in the Kwa Iboe River estuary/lower floodplain.

INTRODUCTION

Several published studies both in Nigeria and elsewhere have shown that petroleum pollution has serious consequences on the ecosystem. Oil spillages are the source of hydrocarbons in industrial water and the contamination of fresh water courses. Gas flaring results in thermal pollution which affect the aquatic life. Also, the flora, particularly in oil producing areas is threatened since species such as mangroves mostly regenerate from seeds rather than by vegetative propagation. Petroleum spillage which results in poor aeration of soils reduces species diversity and inhibit algal metabolism (Boesch et al 1974; Soto et al 1975; Vandermeulen and Ahern 1976; Inevbore 1979; Fagbami et al 1988).

Arising from the observation that there is widespread damage to vegetation in petroleum producing areas (Fagbami et al 1988), due to contamination of soil (Odu 1972), this study aims at analysing soils from areas affected and relatively unaffected by petroleum oil pollution, with a view to understanding the relationships between hydrocarbon levels and soil quality. Hence the basic approach is a comparison of soil property values from several sites identified to contain varying proportions of hydrocarbon concentrations in the soils.

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Study Area

The study area is the coastal plains of the Kwa Iboe River estuary in Southeastern Nigeria. Located in Akwa Ibom State, the soils consists of alluvial/sandy ... s (Fig. 1). In the vicinity, Mobil Producing Nigeria has been exploiting petroleum oil su... 1970, from 137 wells in 37 platforms distributed in 16 oil fields. With increased offshore cr...e production, piping to onshore storage facilities, spillages and gas flaring have pollut... the environment, particularly the soils around the storage facilities.

Methods

Four sites observed to be noticeably affected by petroleum pollution were chosen for the collection of soil data. For the purpose of comparison, four other sites located about 1/2 km from the highly polluted sites were also chosen. Two sites were situated near the settlements of Upenekang and Mkpanak while the other two were situated near the Mobil Tank Farm and on the coastal beachridge sands (Fig. 1).

Each site was divided into three sample units for the purpose of soil sampling. Four soil samples, to a depth of 40 cm were obtained in each unit using a soil corer. The samples were air-dried before laboratory analysis. Total hydrocarbon content was determined by the carbon tetrachloride extraction method. pH was measured in 1:2 soil to water suspension using glass electrode. Available phosphorous was determined by the Bray Method. Cation exchange capacity was obtained as the summation of exchangeable bases (Mg, Ca, K, Na) and exchangeable acidity. Exchangeable acidity was determined by extraction with barium acetate and titration with NaOH. Organic carbon was determined by the Walkley-Black wet oxidation method. Sulphate and aluminium were EDTA extractable; Field moisture was obtained from oven-dry weight of field moist samples. Bulk density was measured in steel cores of volume 550cm^3. The routine methods are contained in Jackson (1962).

RESULTS

Table 1 shows the values of total hydrocarbon content in soils from the four sites. Hydrocarbon levels are high in both soil categories and reflect the extent to which the soils have been polluted. At Upenekang the values range from 394.7 to 627.5 ppm with variation being low and moderate in the affected soils. These values however contrast markedly with those from the relatively unaffected soils (24.8-56.3 ppm). Mkpanak which lies nearer to the Tank Farm has higher values, ranging from 605.8 ppm to 721.3 ppm in affected soils, and 59.8-87.2 ppm in the relatively unaffected soils. Variability within site was similar in all cases, the CVs, being low to moderate.

The Tank Farm area has the highest level of hydrocarbons in soils, whether in affected or relatively unaffected soils. Values range from 1297.5 ppm to 1994.8 ppm in affected soils and 536.3 ppm to 742.8ppm in the relatively unaffected soils. The coefficients of variation were moderate and generally higher in values than at the previous sites. The high levels for the Tank Farm are accounted for by spillage during storage operations and the routine cleansing of the tanks. The lowest hydrocarbon content in unaffected soils was recorded for the coastal sands. Values in the affected soils range from 373.5 ppm to 692.8 ppm. In the relatively unaffected soils the values range from 215.8 ppm to 303.4 ppm. In both soil categories the coefficients of variation were high (49.2 - 62.9%). The coastal sand being highly porous have low levels of hydrocarbons due to percolation and tidal flushing.

Table 2 shows that there is a correlation between polluted soils and some soil properties in the soils. Apart from field moisture content which indicated the estuarine location of samples, there were marked differences in values for soil properties from affected and relatively unaffected soils. Bulk density was considerably higher in affected soils (80.9 - 92.8 gcm^{-3}) than in unaffected soils (76.2 - 90.2 gcm^{-3}). This implies that in the highly polluted soils, root penetration of soils may be hampered. pH values indicated that the highly polluted soils were more acidic (5.5 - 5.9) than the relatively unpolluted soils (5.9 - 6.3). A corresponding trend was observed in the values for exchangeable acidity in both soil classes.

Available phosphorous levels were lower in affected soils (1.3 - 2.1 ppm) and higher in unaffected soils (2.0 - 3.9 ppm) although these values may have been affected by air drying. However, the affected soils indicate exhaustion of soil fertility. CEC values were slightly lower in affected soils than in unaffected soils, probably due to poor replenishment of the cations in the former soil class. Hydrocarbons block soil pores and impair subsurface seepage along the soil horizons. In contrast, the relatively unaffected soils experience a higher replenishment rate from tidal imports and seepage from upland areas. Organic carbon values are perhaps indicative of the vegetation coverage of the soils. Since the highly polluted sites have poor vegetation, organic carbon content in soils were expected to be lower than in the relatively unaffected soils where the vegetation was more luxuriant. However the high values for sulphate (0.3 - 0.8 me/100g) and aluminium (0.4 - 1.4 me/100g) in the affected soils implies that organic litter undergoes a reduction process due to high acid conditions. This contrasts with the low values of sulphate and aluminium in unaffected soils which correlate with high values of organic carbon (4.2 - 9.3%).

DISCUSSION/CONCLUSION

Although crude oil spillage on land is usually localized, pollution of the soil environment could be quite extensive. Variation in total hydrocarbon content of soils indicate decreasing concentrations from sites of active pollution to the peripheries. Its spatial variation depends on the topography; where slopes are steep, petroleum oil is transported by overland flow in films to considerable distances from the centres of active spillage (Ukpong 1992). Low water table in upland locations allows percolation of the hydrocarbons into and through the soil horizons. Lateral seepage also transports hydrocarbons along soil horizons where they may impair aeration and affect the decomposition of litter. Micro depressions may trap and slow down overland flow.

Considerable damage to soils has been observed, particularly in highly poll ted areas. Soil exchangeable cations are poorly replenished in polluted soils. Other soil nutrient properties (phosphorous, organic carbon) indicate lower fertility status for affected soils. The most highly varied properties in the affected soils are exchangeable acidity, phosphorous, C.E.C., organic carbon and aluminium which are nutrient status indicators. The corresponding variability of some of these properties (excluding aluminium) in the unaffected soils indicate that petroleum pollution is incipient to severe soil damage particularly in terms of nutrient levels.

Consequent to deteriorating soil fertility, agricultural activities in communities situated in the lower Kwa Iboe River floodplain/estuary have been on the decrease. Former farmlands have been abandoned, particularly those located near minor water channels where regular flooding helps to spread petroleum films over the land surface. Decreasing acreage for cultivation implies local food shortages and reliance on supply sources outside the lower floodplain/estuarine area.

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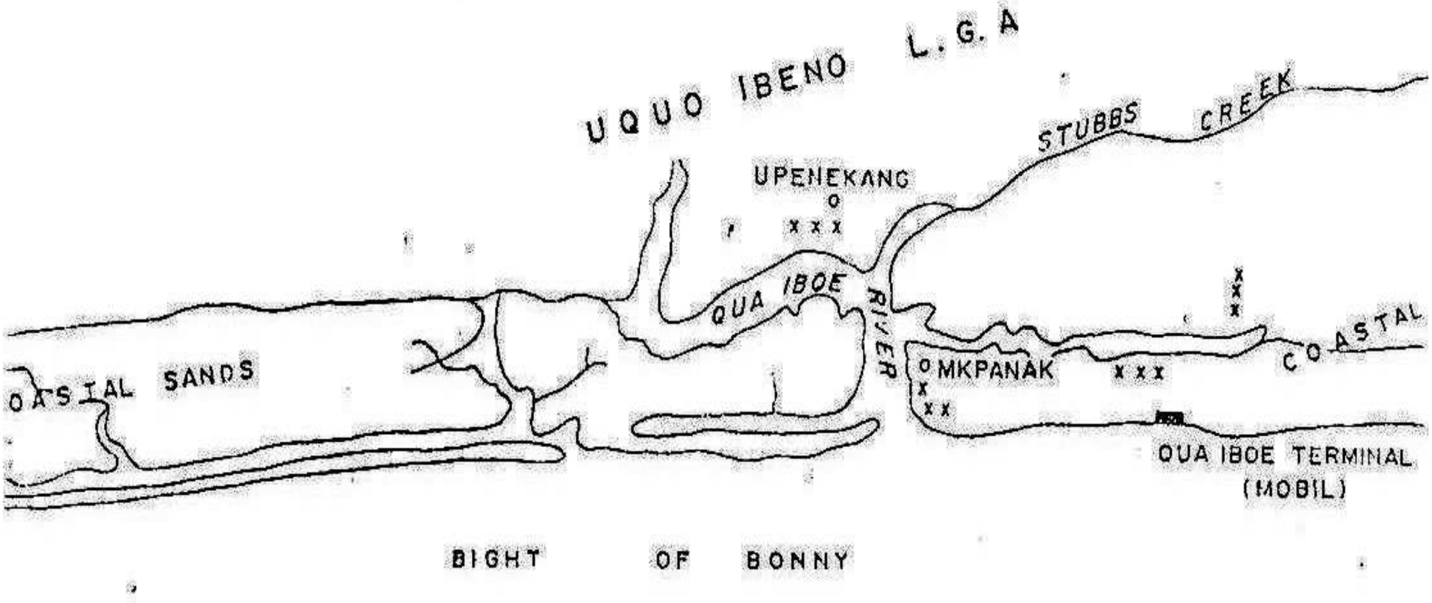
TABLE 1. Total hydrocarbon content in soils affected and relatively unaffected by petroleum pollution near the Kwa Iboe River estuary. Soil depth is 0-40 cm; each THC value, in parts per million (ppm), is mean for at least 4 samples; coefficient of variation (CV) classified as ≤15% = low, 15 - 35% = moderate, > 35% most variable

UPENEKANG					
Affected Soils			Relatively unaffected soils		
$\bar{X}$	SD	CV (%)	$\bar{X}$	SD	CV (%)
1. 502.8	104.2	20.7	42.5	8.3	19.5
2. 627.5	98.7	15.7	56.3	6.9	12.3
3. 394.7	126.5	32.0	24.8	10.5	42.3
MKPANAK					
1. 693.4	99.2	14.3	78.5	15.4	19.6
2. 721.3	120.6	16.7	87.3	22.8	26.1
3. 605.8	113.5	18.7	59.8	28.7	47.9
TANK FARM					
1. 1842.6	428.6	23.3	742.8	220.5	29.7
2. 1297.5	293.4	22.6	536.2	198.3	36.9
3. 1994.8	382.7	19.2	669.4	205.7	30.7
COASTAL SANDS					
1. 375.5	220.4	53.7	215.8	109.3	50.6
2. 692.8	395.6	57.1	303.4	182.4	60.1
3. 380.4	187.3	49.2	254.6	160.3	62.9

TABLE 2: Properties of soils affected and relatively unaffected by petroleum pollution near the Kwa Iboe River estuary; Soil depth is 0-40cm. Each value is mean for at least 4 samples; coefficient of variation (C.V.) classified as : <15% = low. 15-35% = moderate. >35 = most variable.

	Affected Soils											
Soil Properties	UPENEKANG			MKAPNAK			TANK FARM			COASTAL SANDS		
	X	SD	C.V.	X	SD	C.V.	X	SD	C.V.	X	SD	C.V.
Field moisture(%)	128.4	2.7	2.1	137.3	6.3	4.6	119.2	1.8	1.5	102.6	3.5	3.4
Bulk density (gcm⁻³)	92.8	4.6	4.9	88.5	2.1	2.4	80.9	2.8	3.5	90.5	4.1	4.5
pH	5.7	0.4	7.0	5.8	0.3	5.1	5.5	0.4	7.2	5.9	0.3	5.0
Exchange acidity (me/100g)	6.8	1.6	23.5	5.9	2.1	35.6	6.2	1.9	30.6	6.0	2.5	11.7
Phosphorous (ppm)	1.3	0.5	38.4	1.8	0.6	33.3	1.5	0.4	26.7	2.1	0.6	28.6
Sulphate(me/100g)	0.5	0.2	4.0	0.6	0.1	16.7	8.8	0.4	50.0	0.3	0.1	33.3
Aluminium (me/100g)	0.9	0.4	41.4	1.0	0.3	30.0	1.4	0.6	42.9	0.4	0.2	50.0
C E C (me/100g)	38.5	10.5	27.3	42.3	12.3	29.1	34.2	8.2	24.0	44.5	15.3	34.9
Organic carbon (%)	6.8	2.5	36.8	6.5	2.2	33.8	5.8	1.9	32.8	3.2	1.1	34.4

	Unaffected Soils											
Soil Properties	UPENEKANG			MKAPNAK			TANK FARM			COASTAL SANDS		
	X	SD	C.V.	X	SD	C.V.	X	SD	C.V.	X	SD	C.V.
Field moisture(%)	129.6	2.4	1.9	140.2	7.2	5.1	117.8	2.0	1.7	106.4	4.1	3.9
Bulk density (gcm⁻³)	88.2	6.8	7.7	84.6	4.5	5.3	76.2	6.4	8.4	90.2	6.8	7.5
pH	6.1	0.5	8.2	6.2	0.6	9.7	5.9	0.6	10.2	6.3	0.5	7.9
Exchange acidity (me/100g)	4.2	2.5	59.5	4.4	1.9	43.2	5.1	1.5	29.4	4.9	2.0	40.8
Phosphorous (ppm)	2.8	0.7	25.0	2.5	0.8	32.0	2.0	0.4	20.0	3.9	0.8	20.5
Sulphate(me/100g)	0.2	0.08	40.0	0.3	0.09	30.0	0.2	0.01	5.0	0.4	0.02	5.0
Aluminium (me/100g)	0.6	0.04	6.6	0.8	0.05	6.2	0.6	0.02	0.3	0.5	0.01	3.3
C E C (me/100g)	340.6	9.3	22.9	45.5	15.2	33.4	39.4	12.6	31.9	46.8	19.2	41.0
Organic carbon (%)	8.4	1.9	22.6	9.3	2.5	26.9	7.6	2.8	36.8	4.2	1.9	45.2



ure 1: Map of the Study area; xxx= Sampling points