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Impacts of Exploitation and Gas Pipelines on Soils Along Qua Iboe River Estuary of Onna, Southeastern Nigeria

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ABSTRACT

Exploitations are the major threat to the environment of Ikot Ebidang. An overview of the impacts of gas pipeline management activities on soil erosion and productivity was investigated in this community. The present soil condition shows that inherent low fertility status is seldom the cause of greatly reduced site productivity. However, erosion, in combination with other site factors, works to degrade productivity on a large scale. Extreme disturbances, such as excavation and logging, cause the loss of nutrients, and organic matter. These combined losses reduce long-term site productivity and may lead to sustained periods of extended erosion that could exacerbate degradation.

INTRODUCTION

The science and technology of pipelining have progressed to a stage where the probabilities of small insidious leakages have been reduced to practical minimum [1]. Accidents on the other hand can and still do happen which result in significant pollution of the environment. This is particularly so in the case of pollution from gas pipelines, because gas is transported in these pipelines under a considerable high pressure and pipeline leakage could be due to corrosion of pipelines or rupture.

Background information

Ikot Ebidang is mostly a flat-laying and undulating sandy coastal area of low relief. However there were other contrasting recognizable belts of mangrove swamps and flood plains with recent alluvial accumulations together with mangrove mudflat which constitute about 40 % of the community [10]. The Qua Iboe River and its tributaries control the drainage and deposition of sand and clays, along the shoreline and the village is completely riddled with soil erosion scars and rapidly eroding and retreating shoreline.

MATERIALS AND METHODS

2.1 General

Pipelining conducted under correct conditions will reduce the environmental hazard, make room for planting easier, and retain the lower duff material to protect the mineral soil and conserve nutrients to sustain forest productivity. To compare the productivity impacts of soil erosion resulting from pipeline construction, we measured the nutrients status and also use the theoretical models to estimate the erodibility and the potential erosion rate of this area [11]. In a generally nutrient-deficient environment, nutrient imbalance and significant impact on future productivity [12].

2.2 Study Area
Ikot Ebidang is one of the villages in Onna local Government area of Akwa Ibom State, Nigeria. It is contiguous with Qua Iboe River and lies between Longitude 4^{0}36N', and 7^{0}51'E. The area has been cultivated with arable and cash crops for over 50 years. The climate corresponse to typical humid climate zone that is principally influenced by two air masses, the tropical continental air mass (CT) and tropical maritime air mass (MT) [9]

2.3 Sampling points, in-situ measurement and samples collected
2.3.1 Fieldwork survey
Field investigation was along the gas pipelines up to Qua Iboe River estuary at Ikot Ebidang community in Onna local Government area of Akwa Ibom State.

2.3.2 Sampling points
There was no fixed interval for sampling, rather soil samplings were based on the physical changes that were observed along the traverse of the gas pipelines and the adjourning plots at 0-15 cm depth.

2.3.3 In-situ measurement
Soil structure was the only parameter that was measured and described in the field.

2.3.4 Samples collected
The samples collected were from 7 locations along the pipelines and adjourning plots. They were transported to the Department of Soil Science laboratory, University of Uyo and air dried for physico-chemical analysis.

2.4 Laboratory analysis
Soil samples were air dried for physico-chemical analysis. Digested samples were sent to Aluminum Smelter Company (ALSCON) Ikot Abasi for heavy metals reading. The methods adopted for the analysis were the standard analytical methods of analysis.

2.5 Data analysis
Data obtained from the laboratory and model estimates were related to the critical values in order to ascertain the level of its occurrence.

2.6. Quality Assurance and Control (QA/QC) measures adopted
Uncontaminated soil samples were collected into well labeled polyethene bags from the field and were qualitatively transported to the laboratory where they were air-dried, and clogs were crushed and then sieved to collect fine earth for routine and heavy metals analysis. Readings were accurately done with appropriate instruments and unexpired reagents were used.

The following methods of analysis and equipments were adopted for these parameters [6];
The **soil pH** was measured on a pH meter using combination glass electrode. The determination was made in 1: 2.5 soil–solution ratio.

Electrical conductivity at 25^{0}C, EC_{25} was measured in the extract obtained from 1: 2.5 soil–water suspensions, using a conductivity bridge.

Organic carbon content was determined by the dichromate oxidation method of Walkley and Black [13, 6]

Total nitrogen was determined by Kjeldahl digestion and N in the digest measured colorimetrically on Tecnicon Model 11 Auto-analyzer using the Berthelot's reaction.

Available P was estimated by Bray No.1 method (Bray and Kurtz, 1947). Phosphorus in the extract was measured by the blue molybdo-colorimeter method of Murphy and Riley [7]

Cation exchange capacity, CEC was determine by the NH_4OA_C saturation. Samples were leached with neutral NH_4OA_C and the excess salt of NH_4OA_C removed by washing the soil with distilled methylated spirit. The adsorbed NH_4^+ ions were displaced with 1M NaCl solution and the NH_4^+ in the extract determined by titration after distillation into boric acid.

Exchangeable cations were determined in the NH_4OA_C leachate. Ca and Mg were determined by EDTA titration while K and Na were determine on the flame photometer

Bases saturation (BS) was computed as $BS\ \% = \frac{TEB}{CEC} \times 100$

Estimation of **heavy metals** was made by extracting the soil with 0.1 NHCl. The heavy metals were read on the atomic absorption spectrophotometer (AAS).

Mechanical analysis was done by hydrometer method using sodium hexametaphosphate as the dispersing agent. The sand fraction was separated into fine and coarse sands by sieving and textural triangle was used to determine the textural class of the soils

Soil erodibility may be determined by direct measurement in the field plot or by calculated by Wischmeier and Smith [14]. Due to time constraint, and cost of installations, the erodibility of this study site was measured by the nomograph method which is less expensive and time consuming. The method involves the determination of four different soil parameters namely, soil texture, soil structure, organic matter content and profile permeability [3]. The particle size analysis for the determination of soil texture is based on the USDA particle size limits while soil structure and profile permeability were coded according to Wischmeier and Smith [14, 2]

To compute erodibility, the values of these parameters were substituted into the erodibility equation which states that:

$$100k = 2.1m^{1.14}(10^{-4})(12\text{-}a) + 3.25\ (b\text{-}2) + 2.5\ (C - 3)$$

Where;
M = (% silt + % very fine sand) (100 -% clay) a = % Organic matter,
b = structure code (from 1to 6), c = profile permeability class (from 1 to 6),
K = Soil erodibility ($t.ha.h.ha^{-1}mm^{-1}$)

RESULTS AND DISCUSSION

3.1 General

The climate of Ikot Ebidang community like the climate of other part of Akwa Ibom State depend upon the movement of the Inter tropical Discontinuity (ITD), which is a zone separating the warm humid Maritime Tropical (MT) air mass with its associated north easterly winds .The wet season begins in March/April and last till October and is often characterized by heavy storms of short duration with annual mean rainfall of between 2000 and 3000 mm [10] The dry season normally starts around November and is often hot and lasts till March.

3.2 Impact of the pipeline construction on Relief/hydrology/drainage

Pipeline construction significantly affects the relief and ecological relationship within the locality as it is recognized in the agricultural production and productivity to a large extent. It effect individual climatic elements such as radiation, temperature and rainfall, its invariably affect plants, animal and man due to energy and water imbalances. Occasionally, there are thermal stresses which create thermal discomfort, but the most remarkable effects in this area are climate modification and poor plant growth development as already observed.

In recent time, incessant torrential downpours with their associated surface runoff which have seriously affected the community and have created a lot of losses in terms of farmlands and property. Flooding is also a major problem and a lot of damage has been done to farm crops. Associated with erosion and flooding is the silting of spring, stream and other water channels which are valuable sources of water supply in Ikot Ebidang. The significance of pipelining and incurable effect on life and living standard in this community calls for concern.

3.3 Impact of the project on:

3.3.1 Soil physico-chemical properties and fertility

Data related to the soil physical and chemical properties measured are shown in the Tables 1 & 2. The textures of the soils were generally loamy sand. Coarse fraction varied from 22.48 -43.21 gkg^{-1}, while fine sand fraction ranged from47.81-67.32 gkg^{-1}. Silt content ranged from 1.40 -5.48 gkg^{-1} but clay varied from 1.10 – 8.80 gkg^{-1}. Dispersion ratio averaged 4.60 g per kg soil, but varied from 2.40 – 6.48. These soils are predominately coarse textured, a property associated with the parent material which are sand and various complexes of sandstones. On the other hand, silt content in these soils was generally low and varied little with location. The grain size distribution, reveals that the soils have a relative high capacity for adsorption of contaminants because the overall surface area of the soil particles is significantly greater in fine sand than coarse grained

This trend of relative increase in fine sand and a decrease in coarse sand content along the locations is directly proportional to soil loss, also soils containing low amount of clay are easily dispersed and erodible. Furthermore very fine sand (0.05-0.1 mm), is comparable in erodibility to silt-sized particles [14] therefore, one would expect these soils that are low in silt but high fine sand to be prone to erosion as is the case

Table 1. Showing the mechanical analysis of soil along gas pipeline

Locations	Coarse sand gkg^{-1}	Fine sand gkg^{-1}	Silt gkg^{-1}	Silt + FS gkg^{-1}	Clay gkg^{-1}	texture	Dispersion ratio
ON1	36.52	54.2	5.48	59.68	3.8	LS	6.48
ON2	28.6	66.32	2.48	68.8	2.6	LS	3.48
ON3	38.25	57.17	2.48	59.65	2.1	LS	3.48
ON4	37.17	56.25	5.48	61.73	1.1	LS	6.48
ON5	43.21	47.81	5.48	53.29	3.5	LS	6.48
ON6	22.48	67.32	1.4	68.72	8.8	SL	2.4
ON7	36.24	58.56	2.4	60.96	2.8	SL	3.4

LS = loamy sand; SL = Sandy loam ON = Onna

3.3.2 Chemical properties

Details of the chemical properties are given in the Table 2. The soils are all acidic with pH vales ranging from 5.6-5.7. Most of the soils' pH values clustered around 5.6. The electrical conductivity of the soils is generally low in all the locations indicating no salinity problems.

Organic carbons is a complex and valuable mixture of compounds which is alien to soil and their presence affects exchange of oxygen and stain surface soil. The organic carbon content is high most of the locations with a mean value of 7.86 gkg^{-1}. Total N is low in all the locations leading to excessively high C: N ratio. This gives a strong indication of serious nitrogen deficiency in these soils.

The estimated available phosphorus was moderately high and did not vary much among the soil locations. These moderate values of available P is not disturbing when considering the adverse of excessive P (> 20 $mgkg^{-1}$) may have on the availability of micronutrients like Fe and Al (amorphous and crystalline) . These Soils will require a significant phosphorus fertilizer application for any crop, but it is imperative to calibrate the quantity of application base on crop type, if good yields of crops must be achieved.

The exchangeable cations indicate high basic nutrients status in all the locations. Ca varied from 3.36-6.24$cmolkg^{-1}$ with an average of 5.00$cmolkg^{-1}$, Mg, 1.44-1.92, averaged 1.74 $cmolkg^{-1}$ whereas Na was between 0.04 and 0.05 $cmolkg^{-1}$. Exchangeable K at the soil surface is low, it varied from 0.10-0.12 $cmolkg^{-1}$. These soils have K values below 0.21 $cmolkg^{-1}$ which is regarded as critical level for most of the crops [14] Therefore potash fertilizer will in most case be required for profitable crop production.

The percent base saturation is high (> 50 %) indicating low exchange acidity and reflecting the high base status of the soils. As shown in Table 2, the mean values of BS calculated from the effective cation exchange capacity are > 50 %. The low acidity of the soils coupled with the high percent
BS status strongly indicates no acidity problem. Good yields of crop in these soils will required no liming of any sort.

Effective cation exchange capacity (ECEC) of the soils is high. It varied from 8.14-13.28 $cmolkg^{-1}$. The high ECEC indicates high buffering capacity of the soils. But for these soils, the buffering capacity is moderate and these could partially be attributed to the mangrove mudflat in which it derive its form and partly the alteration of the water channel due to gas pipeline that soil water logged the locations.

Table 2. Basic chemical characteristic of soils in the study area

Locations	pH	EC dSm^{-1}	Org. C gkg^{-1}	TN gkg^{-1}	AV.P $mgkg^{-1}$	Ca	Mg $cmolkg^{-1}$	Na	K	EA	ECEC	Base saturation %
ON1	5.6	0.042	6.0	0.08	10.99	6.24	1.44	0.04	0.11	4.80	12.63	61.9
ON2	5.6	0.029	8.5	0.06	11.99	3.36	1.44	0.05	0.11	4.00	8.96	55.4
ON3	5.6	0.038	5.5	0.08	18.99	4.80	1.92	0.05	0.11	6.40	13.28	51.8
ON4	5.6	0.035	9.2	0.05	13.33	4.80	1.92	0.04	0.12	2.88	9.76	70.5
ON5	5.7	0.023	5.0	0.09	10.67	3.36	1.92	0.04	0.10	2.72	8.14	66.6
ON6	5.7	0.023	1.5	0.002	14.33	6.24	1.92	0.04	0.10	4.16	12.46	66.6
ON7	5.6	0.044	5.8	0.08	13.33	6.24	1.44	0.04	0.10	3.52	11.34	68.9

3.3.3 Soil Geology and Erodibility

In the area, the forest though destroyed by human interference and the slope accentuated by excavations slope gently seawards. The crest of the ridge is generally low, less than one meter above water level. It was not possible to study the entire transect in detail at the time of visit due to soil slaking, but it probably like other numerous coastal area with muddy backshore deposit and sandy cliff zone characterized by well sorted fine to coarse sand with shells.

As an increasing threat, soil erosion has attended a high degree of severity and destructiveness. Rills are now destroying agricultural lands especially where excavation was done. Farmlands have been so badly eroded that it has become necessary to discontinue cultivation of the area that were once good farmlands years ago. This devastation is traceable to the backfilling associated with pipeline lying. The soil removed from cultivated lands on the upper valleys set up a chain of damage reaction down valley which is far reaching in their effect.

3.3.4 Structural and erosion parameters

The results of soil structure determined in the field and in the laboratory are presented in Table 3 and Fig. 1(Eroded soil Pix). In the top 0-30 cm depth, the structure varied from weak fine granular structure (WFG) to strong coarse blocky (SCB). Moderate angular blocky (MAB) and medium fine granular (MFG) were also encountered, the structure is predominant massive. Granular structure favours high porosity. This is attributable to the numerous air spaces between them and therefore tends to reduce the micro porosity of the soil as reflected in ponding of water in the location visited.

There is a wide range of coarse sand and clay contents among the locations. The soils also have wide variation of sesqueoxides (Fe and Al oxides) content (Table 3). This is common in coastal mangrove on the Niger Delta region of Nigeria, indicating different degree of weathering. The pedogenic intensity is strongly dependent on the features of the geomorphic surfaces and alluvium materials [1] which are the main factors responsible for the sequential changes of soils along the coast. For suitability of crop and erosion control, factors contributing to these variations include variation in aggregate shape, soil compaction along the catena and of course the soil permeability most be checked.

3.3.5 Soil erodibility

Values of erodibility determined by Wischmeier and Smith (1978), equation are presented in Table 3. Ironically, the erodibility values of these erosion-prone soils were generally low. This might be attributed to the low silt content observed in these soils. Variation of erodibility values between locations is likely to be associated with differences in the OM content, permeability, soil structure and percent silt and very fine sand content. Generally, increase of sheet and rill erosions were pronounced in the disturbed areas.

3.3.6 Potential erosion hazard in the study site.

The product of erodibility K and the average annual EI_{30} erosivity (data not shown) values gives the potential soil loss for a given location. The amount of soil that would lose annually from this newly opened forest soils as exposed to raindrop impact are shown in Table 3. The trend reveals that, the predicted erosion will cause soil loss of 9.87 ton per hectare in a year, but still somewhat less than the rates on sites, particularly areas where excavation was done. As the soil hydrologically impedes following severe removal of top soil, the runoff and erosion rates increase, a characteristic that will soon develop into gully if not checked immediately (Fig. 1).

Since the natural susceptibility of soils in the site (erodibility) is low, the high potential soil losses are directly related to high erosivity values used to multiply the erodibility values. Therefore, one is justified to conclude that widespread soil erosion in Ikot Ebidang community must be blame on high rainfall erosivity and activity of the

SEPTA ENERGY. This is particularly so when the area is characterized by slope and the steepness was accentuated by excavation as is the case in some of the locations.

Fig. 1. Severe removal of top soil, and increase erosion rates at Ikot Ebidang community

Table 3. Showing Structural parameters and erodibility status of the study site

Locations	Structure	Erodibility (t.ha.h.ha^{-1}mm^{-1})	PE t/ha/yr	Crystalline mgkg^{-1}		Amorphous mgkg^{-1}	
				Fe	Al	Fe	Al
ON1	WFG	0.43	9.69082	192.4	96.3	327.4	97.7
ON2	MFG	0.51	9.88104	165.3	73.3	471	10.11
ON3	MAB	0.56	11.02116	166.9	51.1	411.2	121
ON4	SCB	0.53	10.17106	186	41.2	400.9	100.7
ON5	SCB	0.53	10.07106	183.8	32.2	422.1	115.2
ON6	WFG	0.41	9.69102	143	87.2	457.1	143
ON7	MFG	0.45	8.5509	169.9	71.6	431.2	122.7

WFG = weak fine granular, MFG = medium fine granular, SCB= strong coarse blocky, MAB= moderate angular blocky

3.3.7 Heavy metals

The extent to which heavy metals accumulate in the soil as a result of pipelining is seen in Table 4. In all the locations examined, the addition of metals has led to increase in the amount of metallic ions. Although sampling was on the surface soil, there is evidence of considerable movement of Zn, and to a lesser extent of Cd and Ni to a depth below 15 cm as a result of the presence of pipes in the soil. Estimate of the heavy metals concentration (Table 4) revealed that Fe was dominant in all the sampled locations. Fe ranged from 209.00- 232.90 mg/kg soil on the surface layer. Generally, the was no significant change in Fe content among the stations. This level of concentration is capable of causing concretion below the surface layer. Cu varied from 4.11 – 6.43 mg/kg at the surface soil, while Lead ranged from 0.19 -0.41mg/kg with a mean value of 0.28 mg/kg on the surface soil. Zinc varied from 3.17-5.835 mg/kg on the surface. Generally, concentration of Zn was more in the dry season than the wet season. Nickel concentration ranged from 1.11-1.36 mg/kg with a mean value of 1.26 mg/kg. Other elements like Mercury, Vanadium, Chromium, Beryllium and Cadmium were below detectable limit of 0.001 of the analyzing equipment.

The concentration of these heavy metals in the soil is of concerned when the level of concentration is high and becomes a potential pollutant arisen from industrial gas pipeline discharges and dumping of wastes. Heavy metals mostly fine specific adsorption sites in the soil where they are retained very strongly in colloids[15]. The concentration of individual metals in living tissues is ordinary very low and must be maintained within narrow limits to permit the optimum biological performance of most organisms [8] Even though, some heavy metals are essential, Cd and Pb have not been shown to be essential to either plants or animals[3]. Heavy metals will accumulate in the soil as long as the pollutant source remains. It is obvious from Table 4 that Zn is almost present in the highest amount

Table 4. Heavy metal content of the study site

Locations	Cu	Lead	Mercury	Zinc	Nickel	Vanadium	Chromium	Barium	cadmium
	mg/kg								
ON1	6.3	0.31	<0.001	5.83	1.32	<0.001	< 0.001	<0.001	<0.001
ON2	3.96	0.24	<0.001	5.12	1.23	<0.001	<0.001	<0.001	<0.001
ON3	4.11	0.31	<0.001	5.63	1.36	<0.001	<0.001	<0.001	<0.001
ON4	6.43	0.21	<0.001	5.26	1.15	<0.001	<0.001	<0.001	<0.001
ON5	4.26	0.41	<0.001	5.36	1.11	<0.001	<0.001	<0.001	<0.001
ON6	6	0.27	<0.001	4.91	1.36	<0.001	<0.001	<0.001	<0.001
ON7	5.54	0.19	<0.001	3.17	1.28	<0.001	<0.001	<0.001	<0.001

3.3.8 Salinity and organic compounds
As shown in Table 5, variation of salinity on the surface soils was significantly ($p>0.05$) similar at all locations. Salinity level measured a chloride concentration ranged from 8063-13.63 mg/kg on the surface layer .This quantity of stable monovalent salt would not allow availability of soil water to plant due to high osmotic pressure. Thus there was an indication of salt water intrusion in the soil.

Petroleum hydrocarbons are hydrocarbons of petroleum origin. The study area was used for petroleum gas pipelines transportation activities thus necessitating the need for evaluating the total petroleum hydrocarbon content of the soil. Total Petroleum Hydrocarbon concentrations of the soil of the locations area range from 22.22 mg/kg (ON 4) to 48.83mg/kg (ON 5) at the surface level. Less distribution was true for grease & oil in all the stations sampled. This could be accounted for manly from biogenic sources of wax and suberins from decay plants and animals that died due to pollution. The area therefore is contaminated by petroleum gas hydrocarbon.

The poly aromatic hydrocarbons are derivatives of petroleum hydrocarbon compounds. The presence of poly aromatic hydrocarbon in the soil indicates pollution. Aliphatic hydrocarbon, PAH, BTEX, and Phenols were below detectable limit (<0.001mg/kg) of the analytical equipment used. The low level of the organics was not expected because biodegradation and other factors that contribute to the reduction of oil contents in the soil were absent.

Table 5. Salinity and organic compounds of Soils at the study sites

Locations	Salinity as Cl- mg/kg	THC	AH	Oil & grease	PAH	Phenol s	BTEX
ON1	12.10	41.58	<0.001	0.64	<0.001	<0.001	<0.001
ON2	13.63	29.42	<0.001	0.91	<0.001	<0.001	<0.001
ON3	11.46	33.60	<0.001	1.03	<0.001	<0.001	<0.001
ON4	10.30	22.22	<0.001	0.83	<0.001	<0.001	<0.001
ON5	13.30	48.83	<0.001	0.31	<0.001	<0.001	<0.001
ON6	4.87	39.44	<0.001	0.79	<0.001	<0.001	<0.001
ON7	8.63	32.84	<0.001	1.39	<0.001	<0.001	<0.001

3.3.9 Land use
Farming system: The original rain forest was degraded by a systematic practice of cut and burn cultivation, firewood gathering, and lumbering. The major food crops grown are cassava, yam, maize, cocoyam and the cropping system is govern by the cropping calendar.

CONCLUSION

Although some of the locations indicated only trace amounts, it is generally considered that the level of deficiency of these nutrients in its present form couple with other immeasurable variables are likely going to limit the yield of crops to an appreciable extent, particularly for the first crop.

In summary therefore, the amount of hydrocarbon in this location can be used to identify potential and pollution risk faced in this area as a result gas pipeline passage. Therefore having investigated the pollution level during the six years in installation, routine evaluation is necessary to ascertain adequate compensation to the community.

The affinity of soils to retain and decompose pollutants depends on the soil conditions. These soils are capable of transporting vector for pollutant through erosion; the danger of ground water is low. In addition, the interaction of Cd, Ni, with some essential nutrients decreased the vegetative parts of plants in that environment

Recommendations

When contaminants are not removed, any remedial measures under taken will intend to prevent the contaminants from reaching the targets at risk. Therefore, application of vetiver technology becomes eminent. Vetiver is widely used to protect farm infrastructure by stabilizing and reinforcing farmland prone to erosion, thereby increases the area available for cropping. An added bonus is that the planting will provide fodder for cattle during the dry season. This designed measure is durable and requires long term monitoring studies.

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