



Implications of Crude Oil Exploration and Exploitation on Seasonal Variability of pH and Electrical Conductivity of Arable Soil, Water and Sediment of Ibeno Coastal Area, Niger Delta, Nigeria

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Received: February 29, 2024 / Accepted: May 6, 2024

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Abstract

Crude oil exploration in Niger Delta, Nigeria has led to pollution of arable agricultural land, water and air through oil spills, gas flaring, effluent discharge, illegal oil bunkering, pipe line vandalism and artisanal refining. This results in low food production because of decrease in soil nutrients and damage to aquatic life. pH and EC are master variables in agricultural productivity because they determine optimal nutrient availability and soil chemistry. It in this regard that this research was designed to investigate the implications of crude oil exploration and exploitation on pH and Electrical conductivity (EC) on the area. An experimental design method was adopted for this study. Fifteen composite samples each of soil, sediment and water were collected in June 2023 and December, 2023 representing wet and dry seasons, respectively. The soil, sediment and water samples were collected using augers, corers and clean plastic bottles, respectively. Soil and sediment samples were air dried, mechanically ground using a mortar and pestle, and sieved with a 2 mm mesh size and stored for further analysis. Conductivity meter, model Eijlkam K611 and HI98161 - Hanna pH instruments were used to measure the electrical conductivity and pH. The mean pH of the soil, sediment and water for the dry season were 6.633, 6.113 and 6.387, respectively. Also, the mean pH of the soil, sediment and water for wet season were 6.446, 6.226 and 5.867 respectively. The average pH of soil, water and sediment was within the WHO and DPR threshold range of 6.5-8.5. The electrical conductivity of the soil, sediment and water for the dry season were 485.26 $\mu\text{S cm}^{-1}$, 342.86 $\mu\text{S cm}^{-1}$ and 243.00 $\mu\text{S cm}^{-1}$, respectively. The mean electrical conductivity of soil, sediment and water for wet season were 402.86 $\mu\text{S cm}^{-1}$, 316.86 $\mu\text{S cm}^{-1}$ and 298.80 $\mu\text{S cm}^{-1}$, respectively. The electrical conductivity of the soil and

sediment in the dry season was higher than that in the wet season, except water. This research presents data on the seasonal variation of pH and electrical conductivity, (which constitutes important parameters in overall soil chemistry) in soil, sediment and water of Ibeno Coastal Region, Niger Delta available and useful for reference in soil, sediment and water quality.

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Keywords: Electrical Conductivity; pH; Environment; Pollution; Niger Delta

1.0 Introduction

The consistent rise in demand for crude oil, petroleum products, petrochemicals and natural gas has resulted in the proliferation of petroleum and allied industries occasioned by the exploration of more oil wells in the Niger Delta Region of Nigeria. These activities resulted in the pollution of the ambient coastal environment (Nwadinigwe *et al.*, 2014a). The release of pollutants such as heavy metals, poly aromatic hydrocarbons, drilling fluids/mud, spilled crude oil, effluent discharge, and gaseous pollutants, e.g., CO, SO_x, NO_x and soot, into the atmosphere has contaminated the Niger Delta ecosystem. An increase in anthropogenic activities, especially oil exploration and processing, has resulted in the discharge of pollutants into the soil, water, sediment and air, resulting in pollution of the environment. Also, the rise in inhuman population has resulted in attendant anthropogenic activities that threaten the environment, due to the discharge of pollutants from industrial and agricultural activities into the ecosystem (Ubong *et al.*, 2023). Consistent pollution of the soil, water and air represents a growing environmental problem affecting food quality and human health in the Niger Delta region of Nigeria (Nwadinigwe *et al.*, 2015). The telluric ecosystem and shorelines in the oil producing communities of the Niger

Delta are under continuous cultivation. Environmental pollution by industrial and domestic activities may therefore have far reaching implications on the agricultural productivity of the area with multiplier effects on the socio-economic wellbeing of people (Nwadinigwe *et al.*, 2014a, Nwadinigwe *et al.*, 2014b). Contamination of the ecosystem may result from mishandling, deliberate disposal, spilling, and leakage of petroleum products such as gasoline, lubricating oils, diesel fuel, heating oils, used and spent engine oil (Ekanem *et al.*, 2021). Widespread low and high pollution of large areas of agricultural land is a particular problem from indiscriminate sludge discharge from industries, crude oil spills and waste. These can change the balance of the biochemical and geological cycles of the fragile Niger Delta ecosystem. Crude oil contamination of the ecosystem also caused declines in socio-economic activities such as income, education, employment, community safety, recreation and social support.

Crude oil spillage alters soil properties, which affects the overall capacity of the soil to allow optimum growth and development of crops, especially if such occurrences are associated with heavy metals (Onwerenmadu, and Duruigbo 2007). Crude oil spills possess long term effects on soil, water and sediment. The effects of oil

pollution on soil are evidenced by decline in the population of soil microorganisms (Nwadinigwe *et al.*, 2014a). Certain unique species of medicinal, ornamental plants, vegetables and animals in the Niger Delta are now extinct due to pollution (Vwioko *et al.*, 2006). Seasonal changes and oil activities were the key factors affecting soil quality in the Niger Delta region (Udosen *et al.*, 2010).

1.1 Soil pH and electrical conductivity

The pH is the measure of H^+ and OH^+ concentrations. Soil pH is a basic condition with a significant impact on soil biology, chemistry and physical processes that have direct impacts on plant growth and development. Soil and crop productivity is linked to pH (Msimbira and Smith 2020). Hydrogen ion concentration in the soil controls plant chemistry; beyond certain levels of pH, multiple stresses such as hydrogen ion toxicity, and nutrient imbalance, toxicities and deficiencies are induced in plants (Msimbira and Smit 2020). The optimum pH range of the soil appropriate for agriculture activities fluctuates between 5.5 and 7.0. Extreme alkalinity and acidity do not support the healthy growth of the plants. A Change in the pH of the soil affects the availability of nutrients for plant growth. The United States Department of Agricultural National Resources Conservation Service has categorized soil pH as follows: ultra-acidic (<3.5), extremely acidic (3.5–4.4), very strongly acidic (4.5–5.0), strongly acidic (5.1–5.5), moderately acidic (5.6–6.0), slightly acidic (6.1–6.5), neutral (6.6–7.3), slightly alkaline (7.4–7.8), moderately alkaline (7.9–8.4), strongly alkaline (8.5–9.0) and very strongly alkaline (> 9.0) (Burt, 2014). (Okon and Ogba, 2018) reported strong acidity in the soil the Khana, Gokana, Eleme and Tai areas of Rivers State's ecological zone. They concluded that acidity cannot be attributed entirely to the oil spill since other non-oil

producing areas such as Yeghe and Kpong are equally acidic.

Soil electrical conductivity (EC) is the ability of soil water to transmit or attenuate electrical current. Electrical conductivity is an electrolytic process that takes place principally through water-filled pores. The concentrations of Ca^{2+} , Mg^{2+} , K^+ , Na^+ , and NH_4^+ and SO_4^{2-} , Cl^- , NO_3^- , and HCO_3^- determine the EC of soils. EC is used principally to estimate soil salinity, soil moisture and soil depth. Soil EC measurement helps in understanding soil–water–plant relationships. The optimal EC value for plant growth is usually between 0.8-1.8, and should not exceed 2.5. Soil EC like pH, is a good overall indicator of soil fertility. EC is used to show the capacity of the soil to store nutrients. Soils with clay dominated by high cation-exchange capacity (CEC) clay minerals, (e.g., smectite) have higher EC than those with clay dominated by low CEC clay minerals, e.g., kaolinite. Arid soils with a high content of soluble salt and exchangeable sodium generally exhibit extremely high EC.

1.2 Water and Sediment pH and Electrical Conductivity

A very high or low water pH will affect the aquatic organisms, solubility and toxicity of chemicals and heavy metals in the water (EPA, 2012). The majority of aquatic creatures prefer a pH range of 6.5-9.0, though some can live in water with pH levels outside of this range (Fondriest Environmental, 2013). pH affects most chemical and biological processes in water. It is one of the most important environmental factors limiting species distributions in aquatic habitats. Different species flourish within different ranges of pH, with the optimal pH for most aquatic organisms falling between pH 6.5 and 8. Water quality criteria for pH in freshwater suggest a range of 6.5 to 9 (EPA, 2010). Water

conductivity measures the ability of water to transmit an electrical current. Water electrical conductivity is affected by the presence of dissolved inorganic ions, e.g., cations (Cl^{-1} , NO_3^{-} , SO_4^{-2} , and PO_4^{2-}) and anions (Ca^{2+} , Mg^{2+} , K^{+} , Na^{+} , and NH_4^{+}). Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 degrees Celsius (25°C). The electrical conductivity of water assesses the total concentration of solids in the water. Therefore, water EC can be used to determine the quality of the water. Assessment of water quality is very salient for knowing its suitability for different uses (Choubey *et al.*, 2008, Emumejaye and Daniel–Umeri, 2015). The electrical conductivity of streams and rivers is mainly affected by the geology of the area over which the water flows. Waste discharges to water bodies can change the conductivity depending on the compositions of the water. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity. Electrical conductivity between 150 and 500 $\mu\text{hos/cm}$ is the optimal EC range for fishes. Some fish's species of macro-invertebrates cannot survive outside this. The hydraulic conductivity of river sediments ranges from values smaller than 10^{-9} m/s to values higher than 10^{-2} m/s, with dominance in values between 10^{-7} m/s and 10^{-3} m/s. In sediment formation, electrical conductivity is related to the volume and conductivity of the water in earth materials (George *et al.*, 2017). Water quality is fundamental to the health and sustenance of aquatic ecosystems and to hydrology (Udo *et al.*, 2018).

The importance of soil, water and sediment in agricultural and environmental management is evidenced by the vast applications of these ecosystem components in various agricultural,

recreational and other environmental activities. Also, besides the economic and aesthetic damages caused by oil spills, other industrial and domestic activities on plants and animals in both aquatic and terrestrial ecosystems, the environment is greatly affected as most life forms die rapidly as a result of severe pollution in the area. The shoreline of the Niger Delta region is under continuous agricultural activity by indigenes. Therefore: generation of up-to-date baseline data as a reference for regulatory agencies in the formulation of a legal framework to regulate environmental pollution (Udo *et al.*, 2020) and understanding the levels of certain soil, water, and sediment parameters are crucial in assessing the extent of contamination/suitability of arable biota for agriculture or other industrial purposes (Udo *et al.*, 2017). Agitation for the restoration of the polluted environment by the youths has grown into deadly militancy (Nwachukwu and Mbachu, 2018) and Environmental health-related risks are becoming a primary concern in Nigeria, with diverse environmental problems (Hyellai *et al.*, 2021). Studies have shown that about 100% loss in yield of all crops cultivated occurred 200 m away from the Izombe flow station; 45% loss in yield of crops planted 600 m away, and 10% loss for those cultivated 1 km away from the flare point (Anyanwu and Tanee, 2008, Nwachukwu and Mbachu, 2018). Several studies have suggested a need for insights into the current state of land polluted by crude oil (Mafiana *et al.*, 2021). This will determine the suitability of the environment for agricultural purposes and provide quantitative and qualitative data for creating an appropriate remediation effort (Harry *et al.*, 2022).

Furthermore, Agricultural production in soil and water is mostly carried out within a range of pH and EC. pH and EC are master variables in agricultural productivity because they determine

optimal nutrient availability. pH is a “master” variable in the productivity of agricultural soils as it controls soil chemistry and vital metabolic processes like respiration, growth, reproduction and the abundance of species. Also, nutrients solubility, mobility and bioavailability are strongly affected by pH and EC. In the background of agricultural production, pH and EC variation is associated with how the environment is managed before, during and after agricultural activity (Läuchli and Grattan, 2012, Msimbira and Smith, 2020). The frequent crude oil spillage, gas flaring, illegal bunkering, artisanal oil activity and land take going on the Niger Delta region of Nigeria may affect the level of pH, electrical conductivity and other agricultural and climate variables. This may have far reaching adverse implications in agricultural productivity of the study area. Therefore, a full understanding of pH and electrical conductivity of soil, water and sediment is essential before the onset of planting season for efficient management of nutrients and remediation for optimal agricultural productivity. To maintain the soil, water and sediment quality in the shore line of Niger Delta within suitable threshold for agricultural and other socioeconomic activities to thrive, routine monitoring of the ecosystem of great essence (Fubara *et al.*, 2022, Igwe *et al.*, 2021). This research is equally important to investigate and present current soil chemistry data on the selected parameters, to support farmers with scientific data which may guide decisions on crop type and soil fertility management options especially for the study area. Also, during the entire period of this research, there was no published data on the pH and electrical conductivity of the study area and data from this study may serve to guide farmers as they prepare for 2023/2024 planting season and future agricultural activities. It is on this basis that this research work was designed to

determine the level of pH and electrical conductivity of soil, water and sediment of Ibeno Coastal Area, Niger Delta, Nigeria.

2.0 Materials and Method

2.1 The study area

Ibeno Local Government Area has a coastal area of over 1,200 square kilometers. It is situated on the eastern flanks of the Niger Delta, which in turn is part of the Gulf of Guinea. It is located at the southern end of Akwa Ibom State, between latitudes 7°54' and 4°34' north of the equator and longitudes 7°54' and 8°02' east of the Greenwich Meridian. The communities on the west bank of Qua Iboe River do not have access to the hinterland except by boat through the river and creeks. The Qua Iboe River estuary, which lies within the study area coordinates, has Douglas Creek emptying into it. This creek is about 900 m long and 8 m deep. It is the point where petroleum exploration and production (E and P) waste from the ExxonMobil Qua Iboe Terminal (QIT) tank farm is transferred to the lower Qua Iboe River Estuary and adjoining creeks through two 24 diameter pipes. The Exxon Mobil oily sludge dumpsite is located adjacent to this creek and the flare stack, where gas is flared continuously, is also situated. Some communities in Ibeno Local Government Area are located at the bank of the Qua Iboe River, while others are located on the Atlantic Littoral, Mkpanak, Ukpenekang and Iwu-achang, are located on the east bank of the Qua Iboe River, Okoritip and Ikot Inwang are located on the west bank and Iwokpom-Opolom, Itak Abasi, Akete, Okoritak are located on the Atlantic Coast line. Qua Iboe River estuary is in close proximity to the Exxon Mobil oil effluent treatment and discharge plant. The wastes are discharged into the Atlantic Ocean but may recede into the estuary due to tidal motion (Unlag Consult, 1997, Unical Consult, 2023, Udo *et al.*, 2017, Udo *et al.*,

2023).

The study area experiences a typical climate consisting of the rainy season (May to November) and dry season (December to March). The mean monthly temperature during the two seasons ranges between 26.10 °C and 28.2 °C. Relatively low temperatures below 26°C are experienced in the month of January and July October. Local winds experienced along the coastal areas during the dry season are the subdued continental air mass (Harmattan) with an average wind speed of between 0-4m/sec. Onshore south westerly winds are experienced throughout the year, due to the maritime location of the study area. The rainfall for the two seasons ranged between 53.6mm in February to 709.8mm in August. The predominant warm maritime air-mass enables the area to experience two maximum rainfalls. The first season, May through September is characterized by intense monthly rainfall amounts of above 400 mm. The second season (October to early December) is characterized by a relatively lower monthly rainfall of less than 400 mm (Edem *et al.*, 2005, Udo *et al.*, 2017).

2.2 Socio-Economic Characteristics

Ibeno Local Government Area is composed of a few relatively large communities, and many remote fishing settlements. These communities share similar characteristics of heterogeneity in population structure in most communities are filled with a predominant child-age composition, although the sex ratio is almost at equity. The literacy level is low, while Christianity is the dominant religion, although traditional religion still persists and intra-ethnic relations are cordial. The most exploited natural resources are mass of naturally occurring water bodies and vast mangrove vegetation, while capture fisheries, trading, gathering of timber and non-timber forest products and swamp produce, remain the

most important sources of economic livelihood (Edem *et al.*, 2009, Udo *et al.*, 2017).

2.3 Sampling Program Design

The soil, water and sediment sampling for the dry season took place simultaneously in the month of March. The study area was divided into fifteen (15) goe-referenced sampling locations in fifteen communities in the Ibeno Local Government Area, as indicated in the map of the study area in Figure 1. The sampling locations were identified as follows: Location-1(Atabrikang), Location-2 (Ntafre) Location-3 (IkotInwang), Location-4 (Okoritip), Location-5 (Ukpenekang), Location-6 (Okpolom), Location-7 (Iwo Okpom), Location-8(EtoNsek), Location-9 (Afia), Location-10 (AdahaUsuk), Location-11 (Inua Eyet Ikot), Location-12 (Itak Afaha), Location-13 (Iwokwang), Location-14 (Okom Ita), Location-15 (Mkpanak).

2.4 Sampling Collection

Collection of Soil, water and sediment samples
Five samples each of soil, water and sediment from five points at each location were mixed together to form a composite sample representation of that location. At each sample location of the soil sample, all material and organic detritus were removed from the surface. The soil sampler (auger) was used to gather the soil sample from a depth of 1-2 inches. The collected soil samples were placed in a clean bag and labeled appropriately and taken to the laboratory for analysis.

The surface sediment samples were obtained with a 6.5 m diameter corner to a depth of 10 cm. Between each sampling location, the corner was rinsed with distilled water. The sediment samples collected were extruded from the curer into a tray before being stored in clean plastic plates in a cold container until analysis was carried out.

Surface water samples were collected using clean plastic bottles. Clean sampling bottles were filled with pure laboratory water at the site; the bottles were empty and then rinsed several times with the water to be collected. Triplicate samples were

collected at each location and mixed to form one composite sample, giving a total of 15 samples for the study area, a total of 15 composite samples were collected and analyzed for pH and electrical conductivity determination.

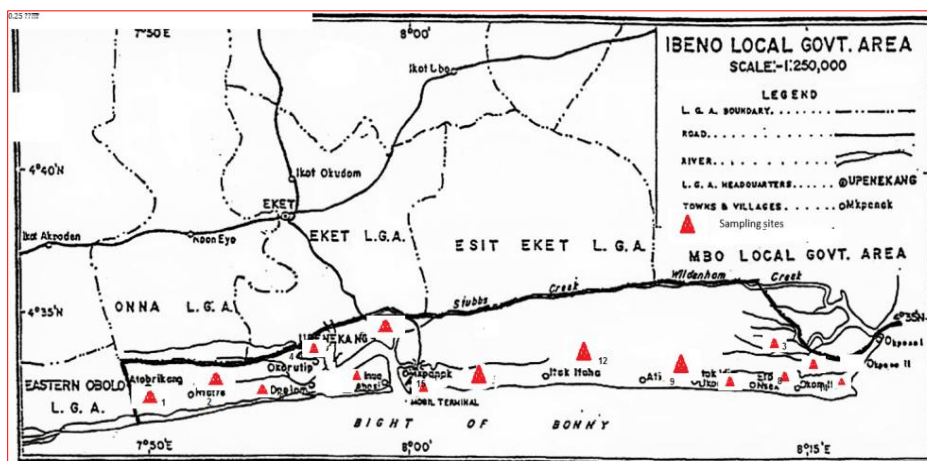


Figure 1: Map of the study area showing sampling locations. Source: Survey and Geo-informatics Department Ministry of Lands and Housing, Akwa Ibom State

2.5 Determination of Electrical Conductivity and pH of the soil, soil and sediment

Exactly 20 g of each of the fresh soil and sediment samples were measured into a clean beaker after removing stones, twigs and larger materials. 40 ml of distilled water was added, stirred vigorously, and allowed to stand for 30 minutes. The soil conductivity was measured as described below (Radojvic *et al.*, 1999). 5.1 g of KCl was diluted to 1dm³ with distilled water in a 1dm³ volumetric flask. 10mL of the above solution was made up to 1dm³. This was the working standard with a conductivity of 100 $\mu\text{mhos cm}^{-1}$ (Radojvic *et al.*, 1999). The soil and sediment electrical conductivities were measured as follows: The working standard was added to a small beaker and the conductivity cell was suspended in the solution, holding it approximately 1.5 m above the bottom of the beaker and making sure that it was not in contact with the wall of the beaker. The reading was adjusted to 100 $\mu\text{mhos cm}^{-1}$. The cell was rinsed

with distilled water and measurements of the electrical conductivity of soil samples for the 15 sample locations and controls were carried out in the same way as described by (Radojevic, *et al.*, 1999) Conductivity meter, model Eijlkam K611 and HI98161 - Hanna pH instruments were used to measure the electrical conductivity and pH of soil, sediment and water, respectively.

3.0 Results and Discussion

The results of pH and electrical conductivity of water, sediment, and soil, in the 15 sample locations of the Ibeno local Government Area during dry and wet seasons are presented in Tables 1 and 2, and Figures 2- 7.

3.1 Soil pH

The mean pH of the soil for the dry season was 6.633 (slightly acidic), but within WHO and DPR standards of 6.5 - 8.5 (Table 1 and Figure 2). Similarly, the mean soil pH during the wet season was 6.446 as presented in (Table 1 and Figure 2), which were slightly acidic but below

WHO and DPR standards of 6.5-8.5. The average pH of (6.540) was recorded for dry and wet seasons and was within the WHO and DPR standards range of 6.5 - 8.5 (Table 1). A Soil pH of 6.00 -7.50 is acceptable for most plants, as most nutrients become available in this pH range. Soil pH is important because it affects the availability of nutrients to plants. Above certain levels of pH, several pressures e.g. hydrogen ion toxicity, and nutrient imbalance, toxicities and deficiencies can be induced in plants (Msimbira and Smith, 2020). The pH variations in the ecosystem have a direct effect on the availability of soil nutrients and plant growth. Soils pH is a critical factor for soil microbial activities. The survival of microbes in certain pH ranges requires the capacity to sense, and adapt to variations in the environment (Biswas *et al.*, 2007). pH is a “master” variable in the productivity of agricultural soils as it controls soil chemistry. The Niger-Delta environment of Nigeria has been consistently stressed by various crude oil production and processing activities going on in the area by various oil companies.

This has resulted in different forms of environmental pollution affecting soil and food quality, with resultant effects on humans as most modern crude oil extraction activities take place in the human population. Hydrocarbons in the crude oil react with the soil components, e.g., salts and minerals converting them from alkaline to acidic (Ehizonomhen *et al.*, 2021).

3.2 Sediment and Water pH

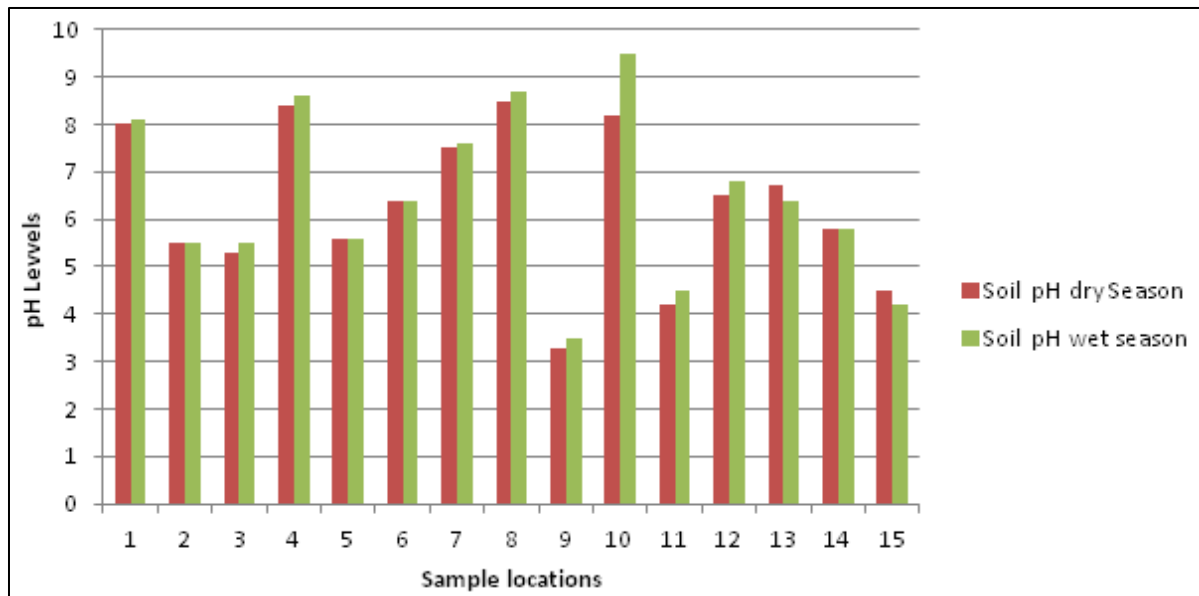
The mean pH levels of sediment for wet and dry seasons were 6.226 and 6.113, respectively (Table 1 and Figure 3) with an average pH of 6.170 but below WHO and DPR threshold standards of 6.5 - 8.5 (Table 1 and Figure 3). The pH of the water samples in the study area showed a significant variation between wet (5.867) and dry (6.387) seasons, respectively, with an average pH of 6.124 for dry and wet seasons (Table 1 and Figure 4). The pH of the water in the study area was below the WHO and DPR standards of 6.5 (Figure 4). The pH value recorded slight variations between different locations and seasons (Table 1 and Figures 2-4).

Table 1: pH Levels of soil, water and sediment in the 15 Sampling Locations

Sampling location	Soil pH dry	Soil pH wet	sediment pH dry	Sediment pH wet	Water pH dry	Water pH wet
1	8.0	8.1	6.2	6.5	5.0	5.5
2	5.5	5.5	6.1	6.2	5.3	5.9
3	5.3	5.5	6.3	6.6	8.4	8.6
4	8.4	8.6	6.5	6.5	5.6	5.6
5	5.6	5.6	5.5	5.8	6.4	6.8
6	6.4	6.4	6.5	6.5	5.4	5.9
7	7.5	7.6	6.4	6.6	8.2	8.2
8	8.5	8.7	6.0	6.0	4.4	6.0
9	3.3	3.5	2.5	4.5	5.2	5.9
10	8.2	9.5	6.5	6.5	6.5	6.7
11	4.2	4.5	6.7	6.7	6.7	6.7
12	6.5	6.8	8.5	8.7	5.8	6.0
13	6.7	6.4	4.0	4.4	3.4	4.4
14	5.8	5.8	6.5	6.5	6.5	6.9
15	4.5	4.2	8.7	8.8	6.2	6.6
Mean	6.633	6.446	6.113	6.226	5.867	6.38
Average of wet + dry	6.540		6.170		6.124	
WHO threshold	6.5-8.5		6.5-8.5		6.5-8.5	

Table 2: Electrical conductivity ($\mu\text{S cm}^{-1}$) of soil, water and sediment in the fifteen sampling locations

Sampling location	Soil EC Dry	Soil EC wet	Sediment EC dry	Sediment EC wet	Water EC Dry	Water EC wet
1	610	499	370	299	214	213
2	350	345	265	260	305	274
3	160	155	227	227	262	251
4	610	598	490	300	351	351
5	480	480	350	345	325	291
6	530	528	251	255	372	358
7	570	564	296	300	355	354
8	280	269	364	359	351	294
9	398	390	254	249	252	252
10	378	368	397	385	335	291
11	620	560	486	399	262	269
12	270	268	476	477	348	340
13	350	345	384	379	348	344
14	336	330	277	270	250	251
15	337	337	256	249	367	349
Mean	485.26	402.86	342.86	316.86	243.00	298.8
Average of wet +dry	444.06			329.86		270.0

**Figure 2:** pH levels of soil samples at different samples locations for dry and wet seasons

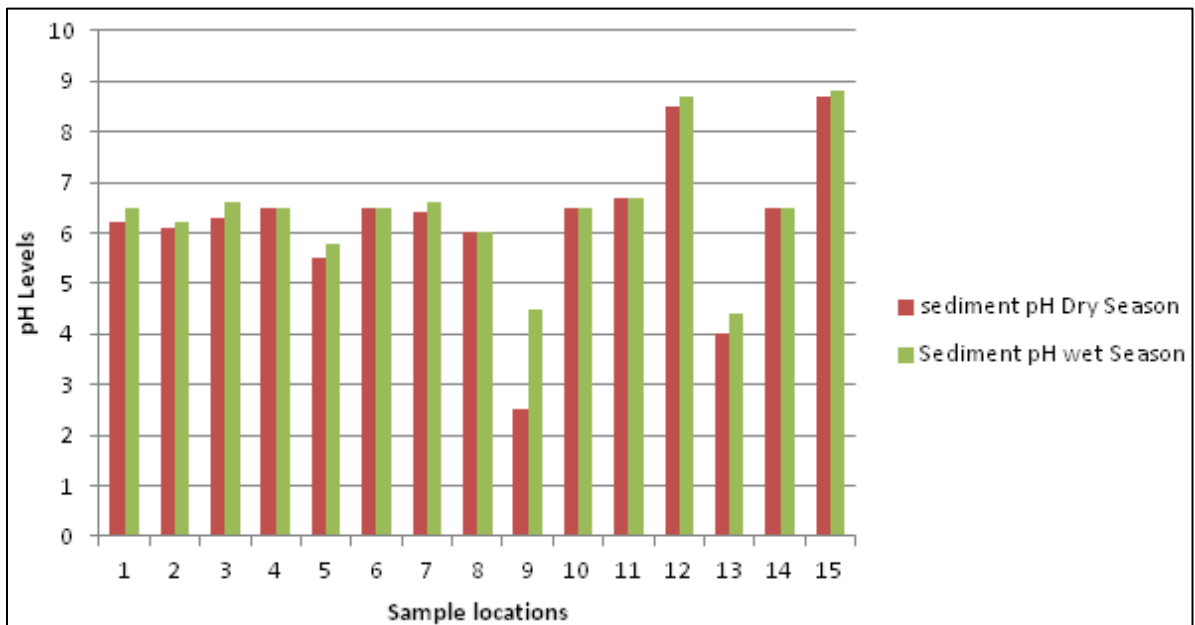


Figure 3: pH levels of sediment samples at different sample locations for dry and wet season

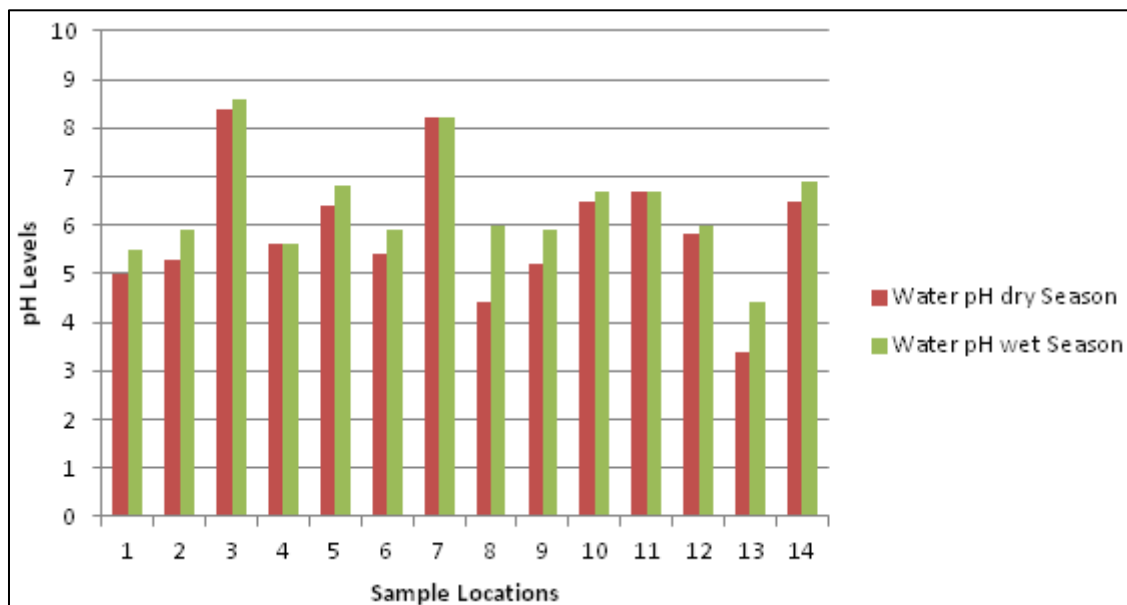


Figure 4: pH levels of water samples at different sample locations for dry and wet seasons.

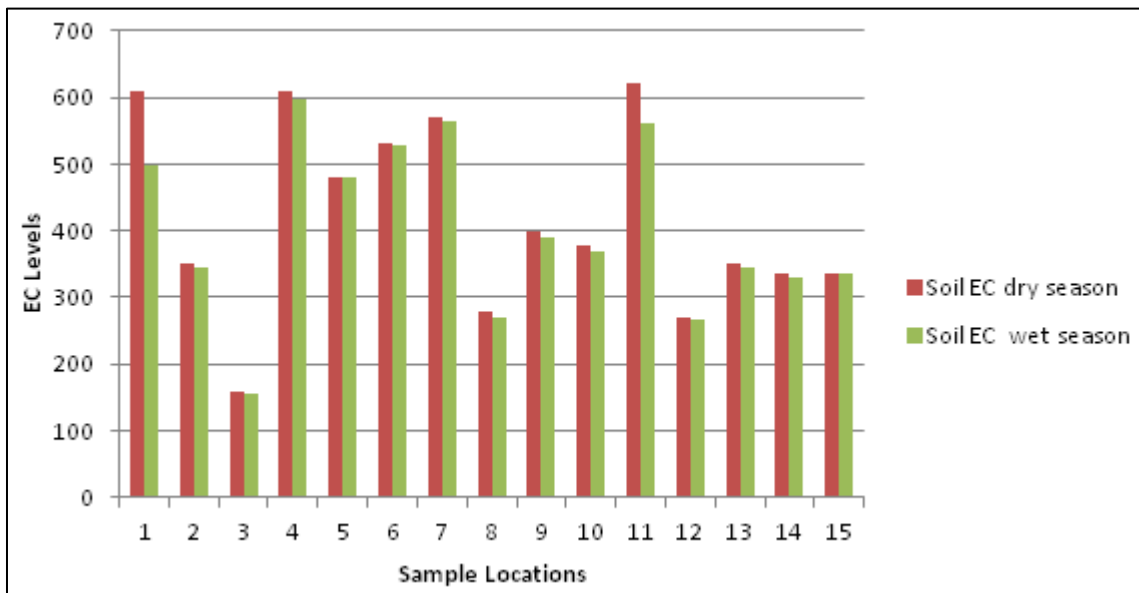


Figure 5: EC levels of the soil samples at different sample locations for dry and wet seasons

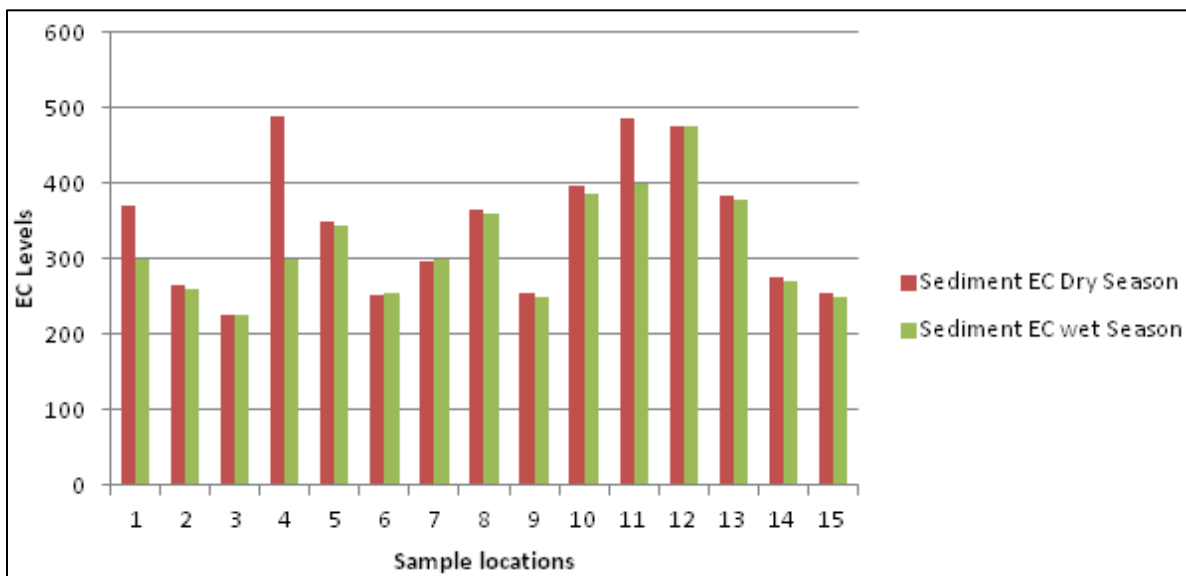


Figure 6: EC levels of the sediment samples at different sample locations for dry and wet seasons

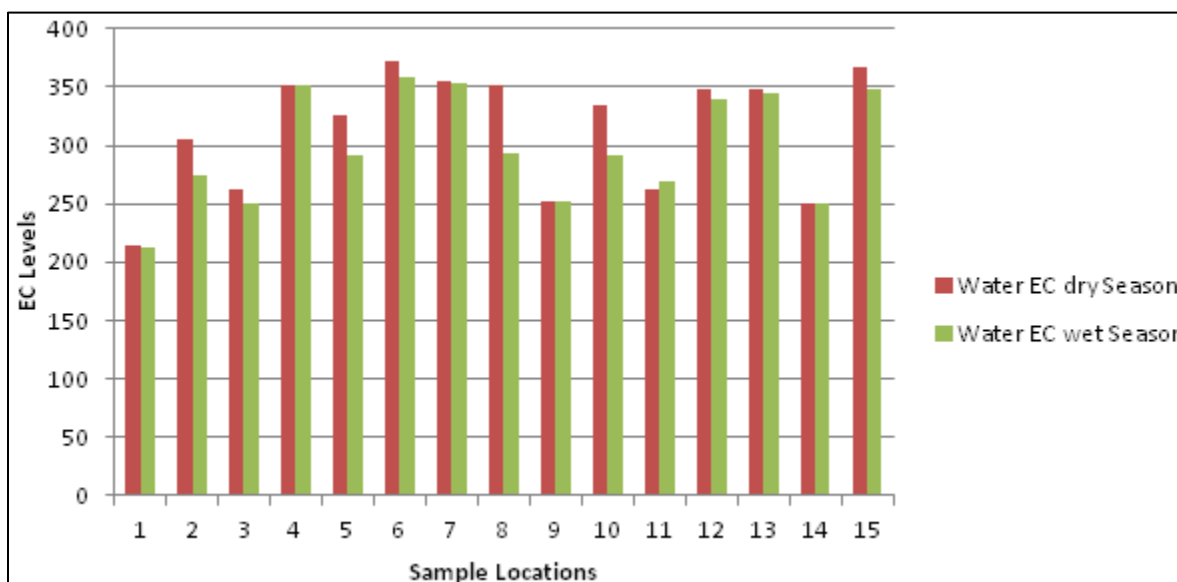


Figure 7: EC levels of the water samples at different sample locations for dry and wet seasons

An elevated pH was recorded in the wet season compared to the dry season in most of the study locations (Table 1 and Figure 4). The mean pH value of 6.381 recorded in the wet season may be associated with the high volume of rain experienced in the area during the wet season (Table 1). This also implied that the season has a significant role in the pH of the study area. The results of this research agree with the work of (Essien *et al.*, 2005) who recorded pH values of 7.27 -7.912 and 6.8 – 7.4 for sediment and water samples, respectively, in the study area and (Ukpong and Peter, 2012) reported a water pH of 6.41. The water pH of 5.8 recorded in this investigation did not meet the WHO standard of 6.5 – 8.5. This signified a disturbance in the ecosystem. In addition, fishes prefer an alkaline aquatic environment; the acidic pH of 5.867 recorded in this study does not support this assertion, and this may indicate pollution in the water of the study area. The change in pH of soil water and sediment could result from fluctuation in temperature and volume of water during dry and wet season. pH is generally higher during periods of low temperature and lower during

periods of high temperature (Sullivan, 2018). Agricultural runoff could be a mechanism that introduced more organic matter to the sampling points during the rainy season (Nguyena *et al.*, 2020) resulting in alteration of the pH and EC of the ecosystems. Also, Pollution sources such as crude oil leakage from pipelines, gas flaring, indiscriminate disposal crude oil sludge, domestic waste disposal and industrial wastes may directly account for the seasonal variation in levels of pH and electrical conductivity. pH is the most important operational water quality parameter because it has an effect on the organisms living in the aquatic ecosystem. It controls vital metabolic processes like respiration, growth, reproduction and the abundance of species. It also affects virtually all enzymes, hormones and other chemical components of the body, which control metabolism and development. Exposure to extreme pH could result in irritation of the eyes, skin and mucous membrane, in sensitive individuals, gastrointestinal irritation may also occur. Exposure to low pH values can also result in similar effects. pH below 2.5 causes damage

to epithelium and can affect the degree of corrosion of metals.

3.3 Electrical Conductivity of Soil, Sediment and Water

The results of the mean electrical conductivity for sediment, water and soil in 15 sampling locations of the study area are as shown in (Table 2 and Figures 5-7). The mean soil electrical conductivity of $485.26 \mu\text{S cm}^{-1}$ was recorded for the dry season and higher than the wet season ($402.86 \mu\text{S cm}^{-1}$) (Table 2 and Figure 5). Similarly, the electrical conductivity of sediment for the dry season was $342.86 \mu\text{S cm}^{-1}$ higher than the wet season's $316.86 \mu\text{S cm}^{-1}$ (Table 2 and Figure 6). On the contrary, water electrical conductivity ($298.80 \mu\text{S cm}^{-1}$) for the wet season was higher compared to the dry season ($243.00 \mu\text{S cm}^{-1}$) (Table 2 and Figure 7). The results of the electrical conductivity of water in the study area agreed with the works of (Ukpong and Peters, 2012), who recorded an average electrical conductivity of $283.1 \mu\text{S cm}^{-1}$ (Udosen *et al.*, 2012) who recorded a mean electric conductivity of $0.4750 \mu\text{S cm}^{-1}$ and (Osuji and Chukwunedum, 2021) who recorded a conductivity of $2,849 \mu\text{S cm}^{-1}$ in the study area. The electrical conductivity of soil water is a good indicator of the amount of nutrient available for crops to absorb (Hovmand, 1983). Conductivity is an indirect measure of ionic concentrations, and increase in conductivity may aggravate potency in soil. Greater understanding of soil electrical conductivity offers useful information for crop management. It is an important characteristic that can be used to map the spatial variation of soil within a production field in nutrient management. There is a strong relationship between soil electrical conductivity and water holding capacity, plant vigour and crop yield.

Salty water conducts electricity more readily than pure water; therefore, electrical conductivity is

routinely used to measure salinity (Onyedika, and Nwasu, 2008). The types of ion-causing salinity are chlorides, sulphates, carbonates, sodium, magnesium, calcium and potassium (Ekundayo *et al.*, 2001). Salinity beyond the normal for any species of organism will cause stress, even death (Sunderman, 1988). Soil electrical conductivity may affect the availability of nutrients to plant roots. The discharge of heavy metals into the water body can raise the conductivity (The Upstream 2004). Several ions are contained in petroleum hydrocarbons, which may combine with the ions in the soil and increase soil EC, which may in turn affect soil productivity (Ehizonmhen, 2021). Knowledge of electrical conductivity in crude oil polluted environments is necessary at regular intervals to guard against nutrient depletion in arable soil and ions imbalanced soil and sediment.

The changes in pH and EC of soil, water and sediment in the study area could result from fluctuation in temperature and volume of water during dry and wet season. pH is generally higher during period of low temperature and lower during period of high temperature (Sullivan, 2018). Agricultural runoff could be a mechanism that introduced more organic matter to the sampling points during the rainy season (Nguyena *et al.*, 2020) resulting in alteration of the pH and EC of the ecosystems. Also, pollution sources such as crude oil leakage from pipelines, gas flaring, and indiscriminate disposal of crude oil sludge, domestic waste disposal and industrial wastes may directly account for the seasonal variation in levels of pH and electrical conductivity

4.0 Conclusion

Although the levels of pH and electrical conductivity in water, sediment and soil in some study locations were higher than WHO and DPR

threshold ranges, the average pH and electrical conductivity of soil, water and sediment were within WHO and DPR recommended standards. The level of pH and electrical conductivity in some study locations can serve as a potential pollution risk indicator of stress in the study area. The importance of pH and electrical conductivity of soil, sediment and water in agricultural and environmental management of the economy of the fragile Niger Delta Ecosystem should not be handled with levity. This is because pH and electrical conductivity are major variables in agricultural productivity because they control soil chemistry. Also, crude oil exploration and processing, other industrial and domestic activities in the Niger Delta region may have far reaching negative implications for the study area. The results obtained in this study could serve as baseline data for farmers, environmentalists, government and other researchers in agricultural and environmental management. Furthermore, considering the various crude oil activities taking place in the Niger Delta environment, coupled with the fact that the soil and water of the region are used for active agriculture purposes, there is a need for periodic monitoring of these ecosystems in order to protect humans and the environment.

Acknowledgements

The authors thank the Department of Pure and Industrial Chemistry, University of Nigeria, Nsukka for their supervisory role. We appreciate the PostGraduate Research laboratory, University of Nigeria, Nsukka for releasing some equipment for laboratory work.

Competing Interests: Authors have declared that no competing interests exist.

Conflict of Interest: The authors declare no conflict of interest.

Compliance with Ethical Standards Declarations: The authors declare that they have no conflict of interest.

Data availability: All data used in this study will be readily available to the public on reasonable demand.

Consent for publication: Not Applicable

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