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Preliminary Assessment of Thermal and pH Properties of Soils in Ogoniland, Rivers State, South-South, Nigeria

Mohammed Maina[1], Othniel K Likkason[2], Nuhu K Samaila[3] and Sani Ali[2]

[1] Department of Science Laboratory Technology, Ramat Polytechnic Maiduguri, Borno State, Nigeria
[2] Department of Physics, Abubakar Tafawa Balewa University, Bauchi, Bauchi State, Nigeria
[3] Department of Geology, Abubakar Tafawa Balewa University, Bauchi, Bauchi State, Nigeria

Corresponding E-mail: mohammedmaina1971@gmail.com

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Abstract

Soil temperature and its variations at different depths are unique parameters that contribute to the understanding of both surface energy processes and regional environmental conditions. This study reports the effects of oil and gas exploration (pollution) on soil thermal properties in Ogoniland, Rivers State, Nigeria. The scope of this study is limited to the determination of the temperature and pH of the soils. A total of thirty (30) soil samples were collected randomly using vegetation, slope, and altitude factors from three (3) local government areas of Ogoniland, Rivers State, Nigeria for determining the point for each sampling, coordinates, and elevation. Soil samples were collected at two depths: 0-15 cm (Topsoil) and 15 – 30 cm (Subsoil) with the aid of a Dutch stainless steel hand auger from four (4) sites (impacted) at different locations within the study area and one (non-impacted) control site outside the project area. A standard digital soil thermometer was employed to determine the temperature of the soils in situ in both regions. It has been observed that the pH and temperature of soils in situ and their variation with test points (location) agree with the results reported in these and similar environments. Hence, it can be concluded that the soils in Eleme, Gokana and Tai Local Government Areas may be recommended, but, with caution, for agricultural activity, laying of gas pipelines, or buried cable in the areas, since the values of these properties observed were within the range of standard values.

Keywords: Depth; temperature; pH; soil.

I. INTRODUCTION

The thermal state of the Niger Delta in Nigeria is influenced by natural phenomena such as weather, climate, radioactivity, and greenhouse effect as well as artificial phenomena such as oil spillage, deforestation and burning of materials which are either flammable or non-flammable [1]. Although the thermal gradient increases with depth, the exposed surface of the Benin Formation is predominantly made to depart from its natural thermal state through man's activities which are either deliberate or otherwise [2]. Apart from the uncontrollable means or the agricultural contributions to the departure of the thermal silicic soil built on the deposits of the high-energy Niger Delta, oil spillage has among other things contributed greatly to the thermal destabilization [3]. The impacts of oil spillage and gas flares have been experienced in Nigeria in recent years and their occurrences are very fast and alarming in the oil-producing communities [4]. Consequently, the threshold limit of the natural thermal state may be exceeded because of the integral contributions of the energy–loaded spill and gas flaring.

Soil temperature depends on the environmental temperature, which also depends on the pore spaces and the material making up the formation [5]. Spillage of crude oil on the soil greatly affects the thermal, chemical, and physical properties of the soil samples, with persistent toxic compounds, such as salts, radioactive materials, or disease-causing agents, adversely affecting plant growth and animal health [6]. When released on the surface soil, petroleum hydrocarbons, with specific physio-chemical characteristics can push soil toward a condition undesirable for proper and sustainable growth of plant and rhizosphere organisms' activity [7], [8], [9].

Currently, about 80% of Ogoniland is polluted by-products of petroleum (hydrocarbons, solvent, etc.) used as a source of energy in the oil industry, as well as chemicals [10], [11]. Various pollutants from crude oil and its byproducts affect the topsoil and subsoil [12]. Crude oil which is abundantly located in the Niger Delta region of Nigeria is spilled on soil due to pipeline vandalization [13], [14]. Previous studies on crude oil pollution and its adverse effect on soil productivity have been reported [15], [16], [17].

Since problems associated with soil pollution affect both agriculture and engineering practices, and alter the soil's physical characteristics like soil texture, compaction, soil temperature, soil pH, thermal conductivity, thermal resistivity and thermal diffusivity and penetration resistance [18], [19], there is a need for continuous research on the problems associated with pollution resulting from spillage and its effects on the soil environment which negatively affect crop production.

This study is primarily focused on the determination of thermal and pH properties of soil samples in Ogoniland, Rivers State, Nigeria and how these values affect the soil environment.

The result of the study would assist policymakers and researchers who may want to engage in environmental impact assessment studies and /or carry out further studies on the depth, temperature, and pH of the soil samples in the study area and elsewhere. It would further serve as a guide for policymakers towards effective policy formulation on depth, temperature, and pH of the soil samples in Ogoniland, Rivers State and Nigeria as a whole.

II. MATERIALS AND METHODS

A. Study Area

The study was conducted in Ogoniland, Rivers State, South-South Nigeria. Ogoniland is situated in the coastal plain of the eastern Niger Delta. Its topography is mainly characterized by rivers, lakes, creeks, lagoons, and swamps of varying dimensions. The land surface can be grouped into three main divisions from the north to the south part: the freshwater zone, mangrove swamps and the coastal sand ridge zone. The riverine area, with a land surface between 2 and 5 m above sea level, covers about 40% of the State, while drier uplands occupy the remainder. Most water channels in the freshwater zone are bordered by natural levees that provide the basis for settlements and agriculture. The upland area varies in height from 10 to 45 m above mean sea level (msl), but the majority is below 30 m. Its surface is interspersed by small ridges and shallow swamp basins, as well as by gently sloping terraces intersected by deep valleys that carry water intermittently. The southern part is subject to tidal influences and is highly susceptible to recurrent inundation by riverine flooding. These flow patterns are responsible for the deposition of fine-grained sediments in the Delta [20].

Ogoniland, like other regions in the Niger Delta, experiences two seasons: rainy and dry season. Rain distribution of 2000 – 3000 mm per annum; and average temperature of 27^0C to 35^0C. The vegetation of Ogoniland is mainly mangrove swamp forests and rich rainforest [21]. It lies between latitudes 4° 05′ to 4° 20′ N and longitudes 7° 10′ to 7° 30′ E (Fig. 1) with a total land area of approximately 1000 km^2 containing nearly up to 116 drilled oil wells and 5 flow stations with a flow station capacity of 185,000 barrels of oil per day [22]. Oil accounts for over 90% of export earnings and about 80% of government revenue. The region is divided administratively into four local government areas: Eleme, Gokana, Khana, and Tai. Traditionally the area is formed by six kingdoms (Babbe, Eleme, Gokana, Ken-Khana, Nyo-Khana, and Tai) and is united under one town Bori, which is the capital (see Fig 1 below). Ogoniland has a population of close to 832,000 and a population density of 1250 km^2 [23], [24]. Despite this high population density, the extraordinary fertility of the Niger Delta soil has historically allowed the Ogoni people to make good living through subsistence farming and fishing [25]. Ogoniland is one of the prominent areas in the Niger Delta region and has been the site of oil industry operations since the late 1950s. It has a calamitous history of pollution from oil spills, gas flares, and oil well fires. The area is naturally endowed with rivers, creeks, and streams. Consequently, it has predominantly traditional fishers and farmers. In the past, it was referred to as the "food basket of the Niger Delta" because it produced cash crops for neighbouring regions within the Niger Delta as well as subsistence agriculture. This traditional practice enhanced the sustainable management of abundant natural resources [26].

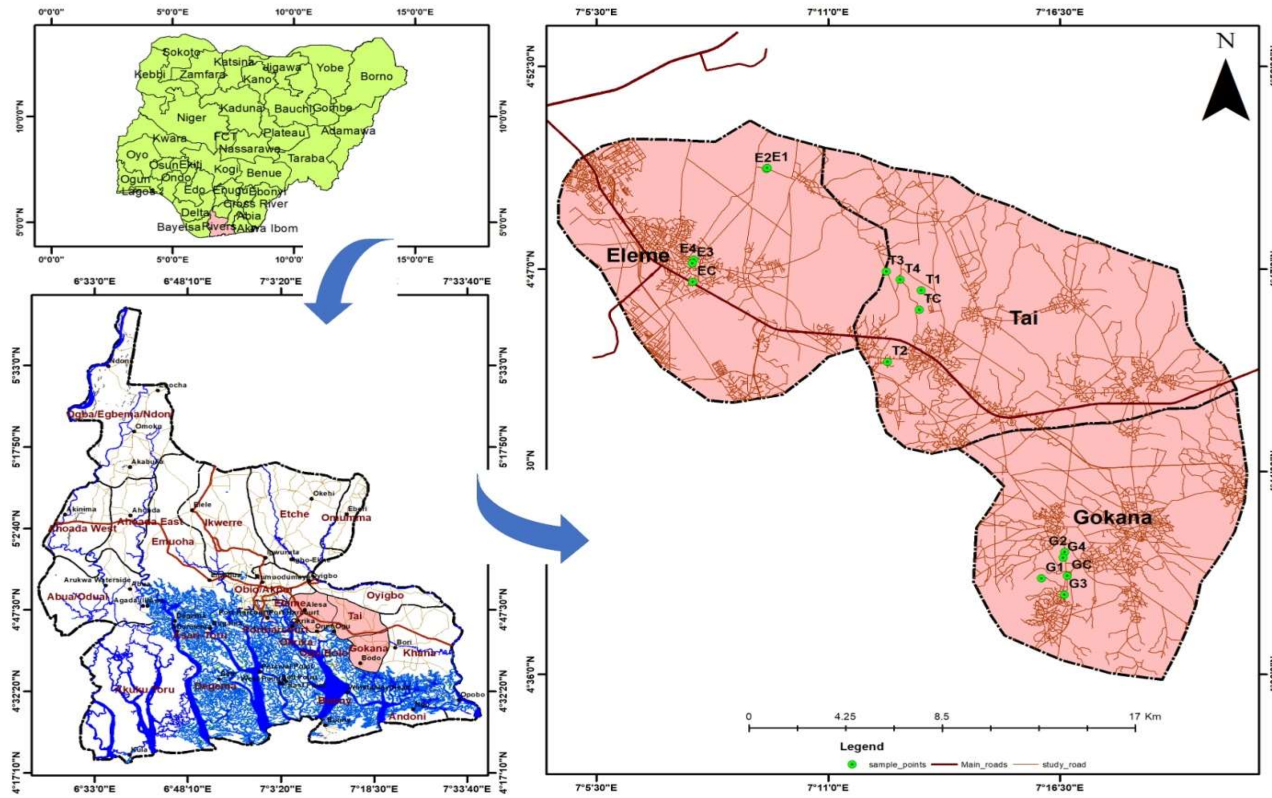

Fig. 1 Locator Map showing Map of Nigeria, Map of Rivers State, Map of Local Government Study Areas (Eleme, Gokana and Tai) in Ogoniland South-South.

B. Materials

The materials used in this research include transparent bottles, soil auger, soil samples, portable digital balance, small containers, polythene bags, Lee Disc Apparatus, thermometers, pH measuring device, stopwatch, basin, mould, oven, standard proctor compaction tool, graduated measuring cylinder, shovel, tray, standard test sieve shaker/machine, a set of B.S. sieve sizes.

C. Methods

1) Sample collection and preparation

Thirty (30) soil samples were randomly collected within the three Local Government Areas, using vegetation, slope, and elevation as the factors determining the point for each sampling, with a GPS reading taken at each point of sampling [27]. The soil samples were collected at two depths: $0-15\ cm$ (Topsoil) and $15-30\ cm$ (Subsoil) with the aid of soil auger from four (4) sites at different locations within the proposed project areas (Impacted) and one (1) Control (Non-Impacted) site outside the project areas. A total of thirty (30) soil samples were collected. The soil samples were collected in Ziploc Polythene Bags for thermal, physical, and chemical analysis. The soil samples were neatly labelled, preserved, and taken to the Analytical Civil Engineering Laboratory, Civil Engineering Department, Ramat Polytechnic Maiduguri - Borno State for analysis. All in-situ observations e.g. soil temperature and soil pH were recorded. The results of the location, longitude, latitude, and depth are presented in Table I-IV.

2) Determination of In-situ Depth of the Soil Samples

This study used the traditional 0-15 cm and 15-30 cm agronomic sampling depth. The soil samples were collected at 0-15 cm and $15-30\ cm$ depths in the four (Impacted) study areas. A pH of 5.0 common to all (Impacted) Sites was recorded and a pH of 7.5 common to all (non-impacted) sites was also recorded on the field. The soil samples were put into polythene bags to preserve their moisture content.

III. RESULTS AND DISCUSSION

Tables I, II and III show Location, Depth, In-Situ Temperature, and pH values in impacted and non-impacted (Control) sites. Table IV gives the In-Situ Temperatures only, obtained for the three Local Government Areas: Eleme, Gokana and Tai.

In Eleme, a temperature variation of 1 ℃ was observed at both Impacted and Control Sites. Temperature variation of $2-3$ ℃ was recorded in the Impacted and Control Sites which may be attributed to oil spillage in the Impacted Site.

Table I. Location, Depth, Temperature, and pH in Impacted and Non-Impacted (Control) Sites Soil Samples obtained at Eleme Local Government Area.

Location	Depth (cm)	Temperature (^{0}C)	pH
Contaminated Soil			
Okulu Ebo	0-15	33	5.0
	15-30	34	5.0
Ogale	0-15	33	5.0
	15-30	33	5.0
Nsisoken	0-15	33	5.0
	15-30	34	5.0
Ajeokpor	0-15	33	5.0
	15-30	33	5.0
Uncontaminated Soil (Control)			
Akenta	0-15	31	7.5
	15-30	32	7.5

Table II. Location, Depth, Temperature, and pH values in Impacted and Non-Impacted (Control) Sites Soil Samples obtained at Gokana Local Government Area.

Location	Depth (cm)	Temperature (^{0}C)	pH
Contaminated Soil			
Goi Waterfront	0-15	32	5.0
	15-30	34	5.0
Kegbara Dere	0-15	36	5.0
	15-30	37	5.0
Kpor Community	0-15	36	5.0
	15-30	35	5.0
Kegbara Dere 2-Joo	0-15	36	5.0
	15-30	37	5.0
Uncontaminated Soil (Control)			
Kegbara Dere 2-Joo	0-15	35	7.5
	15-30	36	7.5

Table III. Location, Depth, Temperature, and pH values in Impacted and Non-Impacted (Control) Sites Soil Samples obtained at Tai Local Government Area.

Location	Depth (cm)	Temperature (^{0}C)	pH
Contaminated Soil			
Baratora	0-15	36	5.0
	15-30	36	5.0
Bara-Ale	0-15	35	5.0
	15-30	35	5.0
Norkpo	0-15	38	5.0
	15-30	37	5.0
Omowawoh Sime	0-15	33	5.0
	15-30	33	5.0
Uncontaminated Soil (Control)			
Gbiwoh Sime	0-15	34	7.5
	15-30	33	7.5

The minimum and maximum temperature in the Impacted Sites is 33 ℃and 34 ℃ respectively with a mean value of 33.25 ℃, whereas in the Control, the minimum and maximum temperature are 31 ℃ and 32 ℃ respectively with a mean value of 31.5 ℃. The high temperature recorded at the Impacted Sites is possibly due to soil contamination by crude oil or its spillage.

In Gokana, a temperature variation of 32 ℃ to 37 ℃ was observed at the impacted sites and 35 ℃ to 36 ℃ was also observed in the Control Sites, and the values may be attributed to oil spillage in the impacted Site. While in Tai, the temperature variation of 5 ℃ $(33 - 38$ ℃) at the Impacted Sites and 10 ℃ $(33 - 34$ ℃) at the Control Sites were obtained. The minimum and maximum temperature in the Impacted Sites is 33 ℃ and 38 ℃ respectively with a mean value of 35.37 ℃, whereas in the Control, the minimum and maximum temperature are 33 ℃ and 34 ℃ respectively with a mean value of 35.5 ℃. However, for soil in a place, the temperature typically varies over a small range to have only an insignificant effect on thermal properties unless the soil freezes [28]. The minimum temperature or specific zero which is the temperature below which plants cease to grow and generally remain dormant is 6 ℃ for most plants while the maximum temperature is 55 ℃ beyond which most plants cannot live without water [29]. From the above results (this study), it could be seen that the temperature values for all the Sites (Impacted and Control) in Eleme, Gokana and Tai LGAs ranged from 31 – 38 ℃, which means that, these values do not reach the maximum. At these temperatures, most if not, all plants can live and grow well if other conditions for plant growth are met.

Table VI shows the temperature of the soil samples obtained at Eleme, Gokana and Tai Local Government Areas. The values shown in the table are within the standard range of value $(6 - 55$ ℃) as reported in other studies [24], [29], [30] [31], [32]. [33], [34], [35], [36], [37], [38].

Table IV shows the pH of Soil Samples in Eleme, Gokana and Tai Local Government Areas. The values shown in Table IV are within the Department of Petroleum Resources (DPR) Standard Range of Measurement of $5.5 - 6.5$ (for Oil Contaminated Soil) as reported in [39]. Table V illustrates the spatial Location of Pit Samples according to Longitude and Latitude at the Research Area in the three LGAs (Eleme, Gokana and Tai).

Fig. 2 and 3 are the 2D Map and Bar Chart of Temperature for Eleme, Gokana and Tai local govt. areas $(0 - 15\ cm)$ respectively. Fig. 2 shows the study sites/locations according to the coordinates, while Fig. 3 give the temperature values within Eleme, Gokana and Tai respectively. The temperature was lowest at Akenta-Eleme (Control) 31 ℃ and highest at Norkpo-Tai (Polluted) 38 ℃. In the same vein, Fig. 4 and 5 are the 2D Map and Bar Chart Temperature for Eleme, Gokana and Tai local govt. areas $(15 - 30\ cm)$ respectively.

Table IV. pH of Soil Samples in Eleme, Gokana and Tai Local Government Areas, Rivers State Nigeria

Eleme			Gokana			Tai		
Location	Depth (cm)	pH	Location	Depth (cm)	pH	Location	Depth (cm)	pH
Okulu Ebo	0-15	5.0	Goi Waterfront	0-15	5.0	Baratora	0-15	5.0
	15-30	5.0		15-30	5.0		15-30	5.0
Ogale	0-15	5.0	Kegbara Dere	0-15	5.0	Bara-Ale	0-15	5.0
	15-30	5.0		15-30	5.0		15-30	5.0
Nsisoken	0-15	5.0	Kpor Community	0-15	5.0	Norkpo	0-15	5.0
	15-30	5.0		15-30	5.0		15-30	5.0
Ajeokpor	0-15	5.0	Kegbara Dere 2-Joo	0-15	5.0	Omowawoh Sime	0-15	5.0
	15-30	5.0		15-30	5.0		15-30	5.0
Akenta (Control)	0-15	7.5	Kegbara Dere 2-Joo (Control)	0-15	7.5	Gbiwoh Sime (Control)	0-15	7.5
	15-30	7.5		15-30	7.5		15-30	7.5

Table V. Spatial Location of Pit Samples according to Longitude and Latitude at the Research Area in the three LGAs.

Y	X	Pit Location	Pit Code	Pit Type	A depth (cm)	B Depth (cm)	LGA
4.782298	7.206262	Norkpo	T3	Pit	0-15	15-30	Tai
4.778619	7.211781	Omowawah-Sime	T4	Pit	0-15	15-30	Tai
4.773712	7.220075	Baratoro	T1	Pit	0-15	15-30	Tai
4.764963	7.219312	Gbiwoh-Sime	TC	Control Pit	0-15	15-30	Tai
4.741415	7.206689	Bara-Ale	T2	Pit	0-15	15-30	Tai
4.828727	7.158839	Ogale	E2	Pit	0-15	15-30	Eleme
4.829077	7.159213	Okulu-Ebo	E1	Pit	0-15	15-30	Eleme
4.787611	7.13007	Ajeokpori	E4	Pit	0-15	15-30	Eleme
4.786038	7.129602	Nsisnoken	E3	Pit	0-15	15-30	Eleme
4.777601	7.129705	Akenta	EC	Control Pit	0-15	15-30	Eleme
4.655257	7.276806	Kegbara-Dere	G2	Pit	0-15	15-30	Gokana
4.652815	7.276242	Kegbara-Dere 2-Joo	G4	Pit	0-15	15-30	Gokana
4.64456	7.277826	Kegbara-Dere 2-Joo	GC	Control Pit	0-15	15-30	Gokana
4.643477	7.267613	Goi Waterfront	G1	Pit	0-15	15-30	Gokana
4.636002	7.276736	Kpo Community	G3	Pit	0-15	15-30	Gokana

Table VI. Temperature of soil samples in Eleme, Gokana and Tai LGAs.

	Eleme			Gokana			Tai	
Location	Depth (cm)	Temperature (°C)	Location	Depth (cm)	Temperature (°C)	Location	Depth (cm)	Temperature (°C)
Okulu Ebo	0-15	33	Goi Waterfront	0-15	32	Baratora	0-15	36
	15-30	34		15-30	34		15-30	36
Ogale	0-15	33	Kegbara Dere	0-15	36	Bara-Ale	0-15	35
	15-30	33		15-30	37		15-30	35
Nsisoken	0-15	33	Kpor Community	0-15	36	Norkpo	0-15	38
	15-30	34		15-30	35		15-30	37
Ajeokpor	0-15	33	Kegbara Dere 2-Joo	0-15	36	Omowawoh Sime	0-15	33
	15-30	33		15-30	37		15-30	33
Akenta (Control)	0-15	31	Kegbara Dere 2-Joo (Control)	0-15	35	Gbiwoh Sime (Control)	0-15	34
	15-30	32		15-30	36		15-30	33

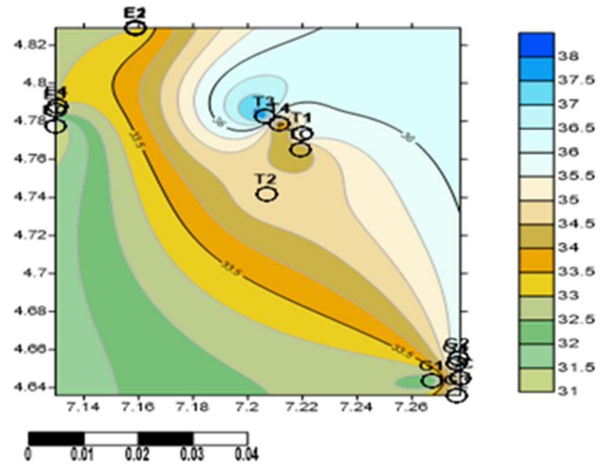

Fig. 2. 2D Map of Soil Temperature at 0 – 15 cm depth (all). Eleme, Gokana and Tai.

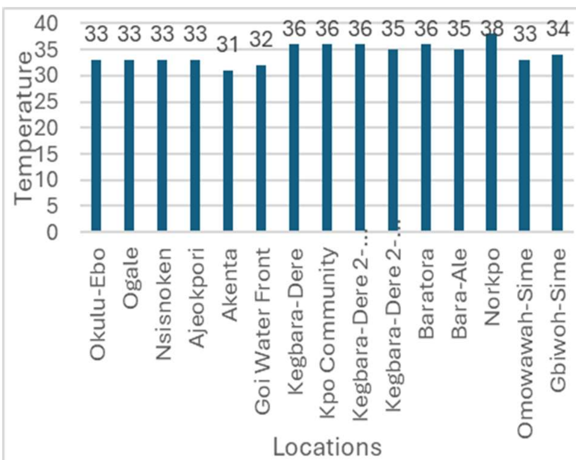

Fig. 3. 2D Bar Chart of Soil Temperature at 0 – 15 cm depth: Eleme, Gokana and Tai.

Fig. 4 shows the study sites/locations according to the coordinates, while Fig. 5 gives the temperature values at the Eleme, Gokana and Tai respectively. The temperature was lowest at Kegbara Dare-Gokana (Polluted) 32 ℃ and highest at Kegbara Dare 2-Joo (Polluted) 37 ℃ and Omawowoh Sime-Tai (Polluted) 37 ℃ respectively. The standard Range of Measurement for Temperature is 6 ℃ for most plants while the maximum temperature is 55 ℃ beyond which most plants cannot live without water [40], [41].

Each plant has a specific pH range for optimal growth. Phosphorous, is one of the three main soil nutrients strongly dependent upon soil pH conditions. A higher pH may also help to immobilize heavy metal contaminants within the soil and can also help to regulate the pH of water entering the stream [38].

A pH of 5.0 (acidic) was recorded, which is common to all Impacted Sites and a pH of 7.5 (almost neutral) common to all Non-Impacted Sites. Considering a pH of 5.0 and 7.5 recorded in this study and a pH of 6 as reported by [42], these range of values are optimal for plant growth. The difference in pH between the Impacted and Control can be due to the contamination of the crude oil or salt concentration in the Impacted Sites. At soil temperature ranges of 31℃ - 34℃ the soil pH increases as a result of organic acid denaturation which increases at high temperature [43]. These observations are in tandem with studies conducted in [44]. The recorded pH (5.0) at the Polluted Sites in this study falls below the DPR range of measurement of 5.5 – 6.5. The presence of hydrogen sulphide which is one of the end products of biodegradation of petroleum, may account for the least value recorded in the Polluted Sites (5.0) which agrees with the finding in [43]. This study revealed that oil production activities had some impact on the soil pH of some study areas mainly Eleme, Gokana and Tai Local Government Areas, and could adversely affect soil fertility and crop production in these areas.

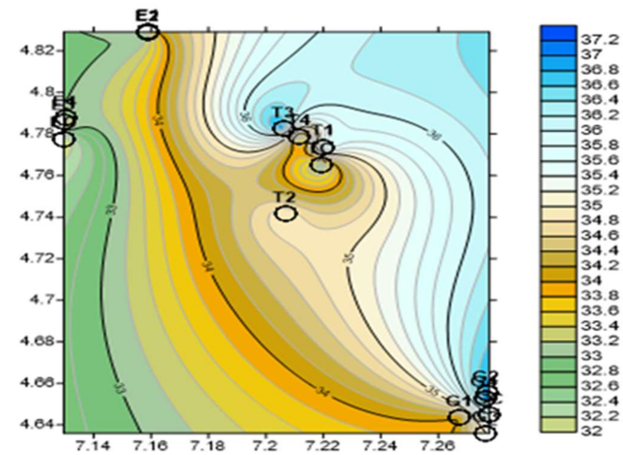

Fig. 4. 2D Map of Soil Temperature at 15 – 30 cm depth: Eleme, Gokana and Tai.

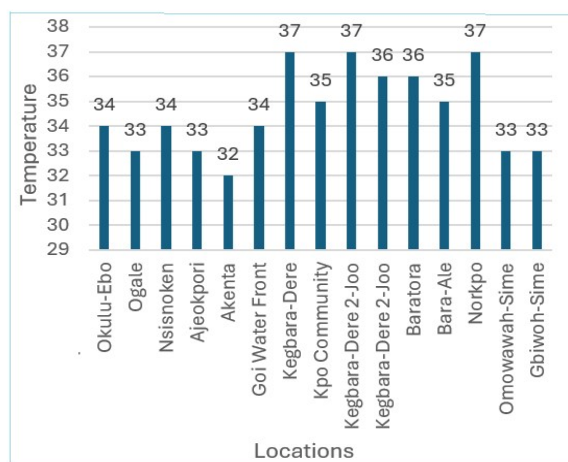

Fig. 5. pH of Soil Samples in Eleme, Gokana and Tai Local Government Areas, Rivers State Nigeria.

IV. Conclusion

The temperature and pH values of soil samples collected within Ogoniland, Rivers State, Nigeria were measured and analyzed. The temperature values of soil samples obtained at Eleme, Gokana and Tai Local Government Areas were all within the standard range of $6 - 55$ ℃ for plants to thrive. Equally, an average pH value of 5.00 was obtained which was far below the control value of 7.00, but slightly below the lower limit of the DPR standard range of $5.50 - 5.60$, denoting the high impact of oil exploration and processing operations in the assessed areas. This strong acidic pH level could lead to an increase in the availability of micronutrients than macronutrients, a reduction in microbial population, a surge in plant uptake of heavy metals, low agricultural productivity, reduced source of livelihood within the affected areas and an increase in toxicity issues. The results obtained can be used in engineering, agriculture, geotechnical and environmental-related activities/issues if other conditions for engineering and plant growth are met.

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