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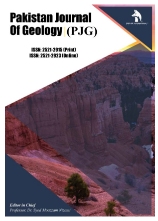

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RESEARCH ARTICLE

INVESTIGATION OF UNDERGROUND PIPELINE CORROSIVITY AS A FUNCTION OF LITHOLOGY AND PORE FLUID IN PARTS OF RIVERS STATE, NIGERIA USING ELECTRICAL RESISTIVITY METHOD

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ABSTRACT

Corrosivity of underground pipeline as a function of lithology and pore fluid in parts of Rivers State, Nigeria was investigated using Wenner array configuration or technique of Vertical Electrical Sounding (VES). A total of six VES were conducted at three locations within Rivers State, the study area and they are Obrikom, Dutch Island and Akpajo each having two VES points. The VES data were collected using ABEM terrameter SAS 300B processed and interpreted using ROCK-WOKS 2017 software and Microsoft excel spread sheet. The apparent resistivity values range from 10Ωm to 200Ωm depicting high corrosivity and indicating that some parts in the study area are likely to be corrosive, increasing the chances of pipeline corrosion (failure) which may result to oil spillage around such areas in the nearest future. Some other parts have negligible apparent resistivity ranging from 200Ωm and above. The Wenner array method used has been proven to be safer, efficient, quick and economical for detecting corrosivity along buried pipelines. The designated corrosivity status of each area were determined by lithology of the area and their resistivity. The knowledge of this study can be applied in the improvement of transmission pipe1ine integrity and reliabi1ity practice, by detecting pipeline damage at ear1y stage as well as oil spillage control and pollutions in areas where underground pipelines are laid.

KEYWORDS

Corrosion, Apparent resistivity, Lithology, VES, Pipeline.

1. INTRODUCTION

Studying the corrosiveness of buried metallic materials in soil is essential as drinking water, petroleum products and other chemicals all over the world are supplied through millions of kilometres of the buried pipelines. (Kirmeyer et al., 1994). Soil corrosion is termed a threat to buried pipelines and have been a major concern for pipe1ine owners in the past decades. Buried steel pipelines are widely used to transport water, gas, oil, and other fluids to serve cities around the country (Yahayya, 2011). Underground pipe1ine systems have advantages in terms of reliability, cost and efficient means of transporting massive amounts of liquid and gaseous products. At the same time, the pipeline industry has experienced a considerable number of unforeseen accidents due to pipeline failure over the years. Pipeline failure had result to the loss of billions of investment as such, pipeline system integrity and reliability have become the number one priority in the transportation industry (Hopkins, 1995).

Corrosion is defined as the degradation of a materia1 or its properties due to its reaction with the environment in which it is immersed (Schmitt, 2009). This gradual destruction affects metals, and it is produced by a chemical or electrochemical reaction with the environment surrounding it (Alter and Maestres, 2004). Soil corrosion may be considered to encompass all corrosion taking place on buried structures (Davis, 2000). A researcher defined soil corrosion as the deterioration of metal or other materials brought about by chemical, mechanical, and biologica1 action in a soil environment (Chaker, 1989). Soil conditions are completely different from other environments, such as the atmosphere. The variation of underground environments causes different soils conditions, even when they are geographically close. This factor greatly hinders the estimation of the sizing of the metallic structures that are going to be buried in the design phase.

Corrosion has been defined to have a negative impact on metallic material causing it to undergo chemical reactions after interacting with the environment (Roberge, 2000). Carbon steel pipelines are basically used to convey hydrocarbon from jackets to production platforms and to storage tanks before the products are exported with loading vessels or transported to local refineries by trunk, pipelines are considered the safest and cost-effective means of hydrocarbon transportation in large volume over long distance despite their susceptibility to corrosion attack (Ameh and Ikpeseni, 2017). When a pipe is buried, it becomes naturally exposed to corrosive environment.

Soil chemical properties is regarded as one of the factors affecting buried pipes. The chemical constituents of soil react with the surface of unprotected buried pipes, which in turn results in the corrosion of such pipes (Romanoff, 1957). However, there is still no complete preventive solution to the corrosion caused by the chemical constituents of soil even in the presence of advanced corrosion protection techniques (Kleiner and Rajani, 2001). The results of this study are very important because of severe and large-scale oil spillages experienced in these areas that had impacted and still impacting seriously on the wellbeing of the people of the areas, from which there had been blames and counter-blames of companies on equipment failures due to corrosion of the pipelines.

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2. Geology and Location of the Study Area

2.1 Geology of the Study Area

Rivers State and its environs forms part of Niger Delta Complex with the usual Benin formation and low land zones of south- eastern Nigeria. It is made up of extensive river line area all the way through which the river Niger links the Atlantic, divided into several distributions which empty in the sea. The deltaic plains consist of sands that are not consolidated, and the sizes of grains ranges from coarse to medium forming lenticular layers with intercalation of peaty matter and lenses of soft, silt clay and shales (Amechi, 1996).

2.2 Location of the Study Area

The study area comprises of selected areas within Rivers State and its environs, the areas are Dutchi Island in Okrika local government area, Akpajo in Eleme local government area and Obirikom in Ogba-Egbema-Ndoni loca1 government area, all in Rivers State. The base map of the VES points shows the areas where the surveys were carried out as shown in Figure 1. There were no criteria for site selection, it was chosen randomly.

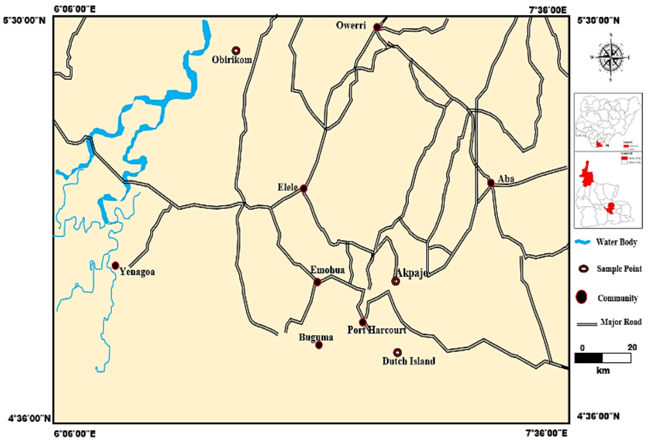

Figure 1: Map of Rivers State Showing the Study Area

3. Materials and Methods

The materials used for carrying out the Vertical Electrical Sounding (VES) used for this study includes Abem terrameter SAS 300B, 12 volts battery as power source, two current electrodes, two potential electrodes, measuring tape, reels of wire (electric cables), hammer, global positioning system (GPS), clips and field data sheet for recording. The Wenner configuration of Vertical Electrical Sounding (VES) method is the method employed in this study. This was carried out with a resistance meter that gives the value of ground resistance R directly, the four electrodes (current and potential electrodes), inline and at the same distance were push into the ground to a depth about 0.4m in such a way as to guarantee close electrical contact with the ground. The value of the apparent resistivity, ρ_a *was* obtained using:

$$\rho_a = 2\Pi a\left(\frac{\Delta V}{I}\right) \quad (1)$$

Where ρ_a = Apparent resistivity

$2\Pi a$ = Geometric factor

$\left(\frac{\Delta V}{I}\right)$ = R = Resistance

3.1 Field Procedure

The configuration used in the data acquisition is the Wenner Array, 12 fixed point called the VES stations were marked and noted, the four electrodes are symmetrically positioned along a straight line, the current electrodes on the outside and the potential electrodes on the inside. The electrodes were pegged into the ground at the normal distance ratio of current electrodes to potential electrodes from the fixed point at AM=MN=NB=a, where AB is the total distance spacing for the current electrode, and MN is the spacing of the potential electrodes.

The field equipment used for this study is the ABEM Terrameter SAS 300 which displays apparent resistivity values digitally as computed from Ohm's law. It is powered by a 12 volts DC power source. Total of six vertical electrical soundings (VES) were carried out at the three locations within the study area as follows, two points at Obrikom, two points at Akpajo and two points at Dutch Island (Table 1). The current electrode spacing varied from 6.0m to 162.0m and the potentia1 e1ectrode spacing range from 0.5m to 10.0m.

3.2 Field Data Analysis and Interpretation

After acquisition of data from the field, the data was analysed with the aid of a computer iteration program. The process involves the use of geophysical software called ROCK WORKS 2017. Field data were inputted into the program, modelled for final interpretation and establishment of conclusion.

Table 1: Geographic References for Sampling Station across the Study Area

S/No.	Location	Northings	Eastings	Line Direction
	Dutch Island			
1	D1	517361	286544	North-South
2	D2	517850	287133	North-South
	Obirikom			
3	L1	598057	237326	North-South
4	L2	598220	237623	East-West
	Akpajo			
5	B1	537069	288629	East-West
6	B2	537728	288317	East-West

3. Results and Discussion

3.1 Results

3.1.2 Resistivity Survey Results Presentation

The results of the resistivity survey carried out are presented in Tables 2 – 3, 4 – 5 and 6 – 7 for Obirikom, Akpajo and Dutch Island respectively. Figures 2, 3 and 4 are resistivity curves showing the recorded resistivity measurements with depth in Obirikom, Akpajo and Dutch Island respectively. In Obirikom and Akpajo, the maximum probed depth recorded is 20 m, while the maximum probe depth of 10 m was recorded in Dutch Island. The maximum probed depths are sufficient1y below the depth of buried pipe1ines which is less than or equal to 6m in these areas.

3.1.3 Soil Corrosivity Mapping

The soil corrosivity interpreted from resistivity measurements as a result of underground pipeline corrosion in Obirikom, Akpajo and Dutch Island are presented in Figures 5, 6 and 7 respectively.

Tab1e 2: Resu1ts of Resistivity Survey Conducted in Obirikom (L1)

AB (m)	E1ectrode Spacing, a (m)	MN/2 (m)	Geoelectric Constant, K	Resistance (Ohm)	Apparent Resistivity (Ohm.m)	Depth of Probe (m)
1.50	0.50	0.25	3.14	46.72	146.70	0.50
2.25	0.75	0.38	4.71	29.15	137.30	0.75
4.50	1.50	0.75	9.42	11.67	109.93	1.50
6.00	2.00	1.00	12.56	9.11	114.47	2.00
7.50	2.50	1.25	15.70	7.89	123.92	2.50
10.50	3.50	1.75	21.98	6.85	150.65	3.50
15.00	5.00	2.50	31.40	5.85	183.78	5.00
22.50	7.50	3.75	47.10	4.50	212.04	7.50
30.00	10.00	5.00	62.80	4.17	261.56	10.00

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Tab1e 3: Resu1ts of Resistivity Survey Conducted in Obirikom (L2)

AB (m)	E1ectrode Spacing, a (m)	MN/2 (m)	Geoelectric Constant, K	Resistance (ohm)	Apparent Resistivity (Ohm.m)	Depth of Probe (m)
1.50	0.50	0.25	3.14	53.34	167.49	0.50
2.25	0.75	0.38	4.71	40.77	192.03	0.75
4.50	1.50	0.75	9.42	16.29	153.45	1.50
6.00	2.00	1.00	12.56	12.01	150.85	2.00
7.50	2.50	1.25	15.70	9.14	143.51	2.50
10.50	3.50	1.75	21.98	7.36	161.77	3.50
15.00	5.00	2.50	31.40	6.20	194.55	5.00
22.50	7.50	3.75	47.10	4.78	225.28	7.50
30.00	10.00	5.00	62.80	4.14	259.68	10.00

Tab1e 4: Resu1ts of Resistivity Survey Conducted in Akpajo (B1)

AB (m)	E1ectrode Spacing, a (m)	MN/2 (m)	Geoelectric Constant, K	Resistance (ohm)	Apparent Resistivity (Ohm.m)	Depth of Probe (m)
1.50	0.50	0.25	3.14	61.75	193.90	0.50
2.25	0.75	0.38	4.71	47.33	222.92	0.75
4.50	1.50	0.75	9.42	38.22	360.03	1.50
6.00	2.00	1.00	12.56	36.12	453.67	2.00
7.50	2.50	1.25	15.70	30.03	471.47	2.50
10.50	3.50	1.75	21.98	23.48	516.09	3.50
15.00	5.00	2.50	31.40	16.64	522.50	5.00
22.50	7.50	3.75	47.10	12.74	600.05	7.50
30.00	10.00	5.00	62.80	11.63	730.36	10.00
45.00	15.00	7.50	94.20	7.63	719.12	15.00
60.00	20.00	10.00	125.60	3.50	439.85	20.00

Tab1e 5: Resu1ts of Resistivity Survey Conducted in Akpajo (B2)

AB (m)	E1ectrode Spacing, a (m)	MN/2 (m)	Geoelectric Constant, K	Resistance (ohm)	Apparent Resistivity (Ohm.m)	Depth of Probe (m)
1.50	0.50	0.25	3.14	21.77	68.37	0.50
2.25	0.75	0.38	4.71	17.20	80.99	0.75
4.50	1.50	0.75	9.42	10.93	102.99	1.50
6.00	2.00	1.00	12.56	9.76	122.55	2.00
7.50	2.50	1.25	15.70	8.34	130.98	2.50
10.50	3.50	1.75	21.98	7.63	167.65	3.50
15.00	5.00	2.50	31.40	6.60	207.16	5.00
22.50	7.50	3.75	47.10	5.08	239.34	7.50
30.00	10.00	5.00	62.80	4.29	269.68	10.00
45.00	15.00	7.50	94.20	3.02	284.40	15.00
60.00	20.00	10.00	125.60	1.97	247.28	20.00

Tab1e 6: Resu1ts of Resistivity Survey Conducted in Dutch Island (D1)

AB (m)	E1ectrode Spacing, a (m)	MN/2 (m)	Geoelectric Constant, K	Resistance (ohm)	Apparent Resistivity (Ohm.m)	Depth of Probe (m)
1.50	0.50	0.25	3.14	0.58	1.81	0.50
2.25	0.75	0.38	4.71	0.32	1.52	0.75
4.50	1.50	0.75	9.42	0.17	1.63	1.50
6.00	2.00	1.00	12.56	0.11	1.32	2.00
7.50	2.50	1.25	15.70	0.27	4.24	2.50
10.50	3.50	1.75	21.98	0.48	10.44	3.50
15.00	5.00	2.50	31.40	0.04	1.32	5.00
22.50	7.50	3.75	47.10	0.10	4.57	7.50
30.00	10.00	5.00	62.80	0.09	5.46	10.00

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Table 7: Results of Resistivity Survey Conducted in Dutch Island (D2)						
AB (m)	**E1ectrode Spacing, a (m)**	**MN/2 (m)**	**Geoelectric Constant, K**	**Resistance (ohm)**	**Apparent Resistivity (Ohm.m)**	**Depth of Probe (m)**
1.50	0.50	0.25	3.14	0.38	1.18	0.50
2.25	0.75	0.38	4.71	0.36	1.71	0.75
4.50	1.50	0.75	9.42	0.35	3.33	1.50
6.00	2.00	1.00	12.56	0.35	4.43	2.00
7.50	2.50	1.25	15.70	0.32	5.04	2.50
10.50	3.50	1.75	21.98	0.34	7.52	3.50
15.00	5.00	2.50	31.40	0.33	10.36	5.00
22.50	7.50	3.75	47.10	0.34	16.20	7.50
30.00	10.00	5.00	62.80	0.32	20.28	10.00

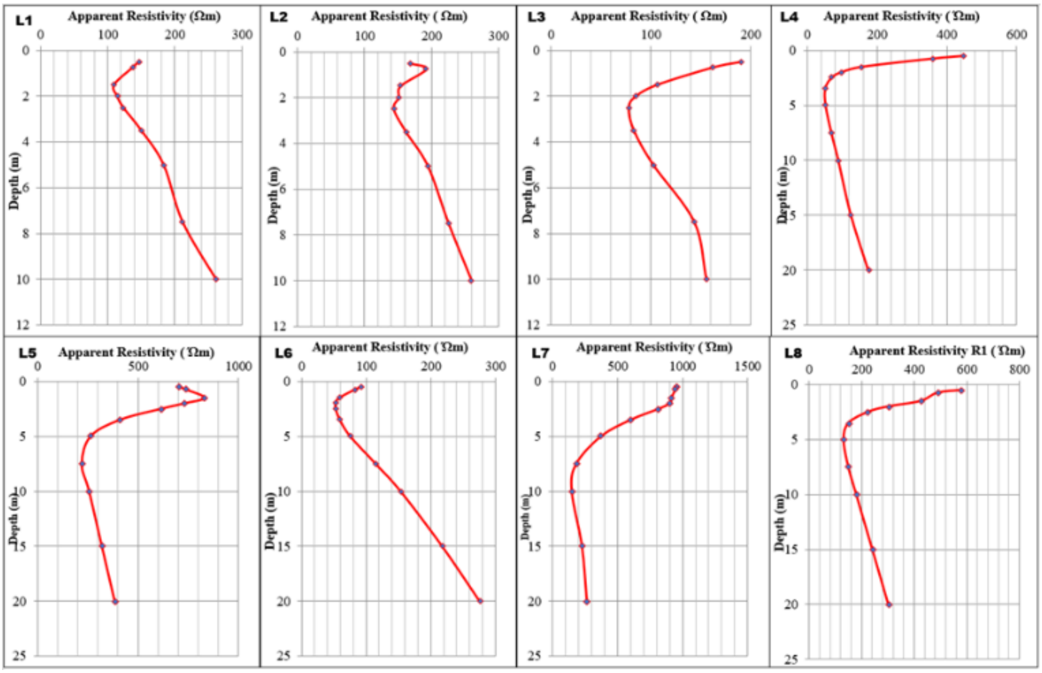

Figure 2: Resu1ts of Measured Apparent Resistivity P1otted Against Depth for Survey Conducted in Obirikom

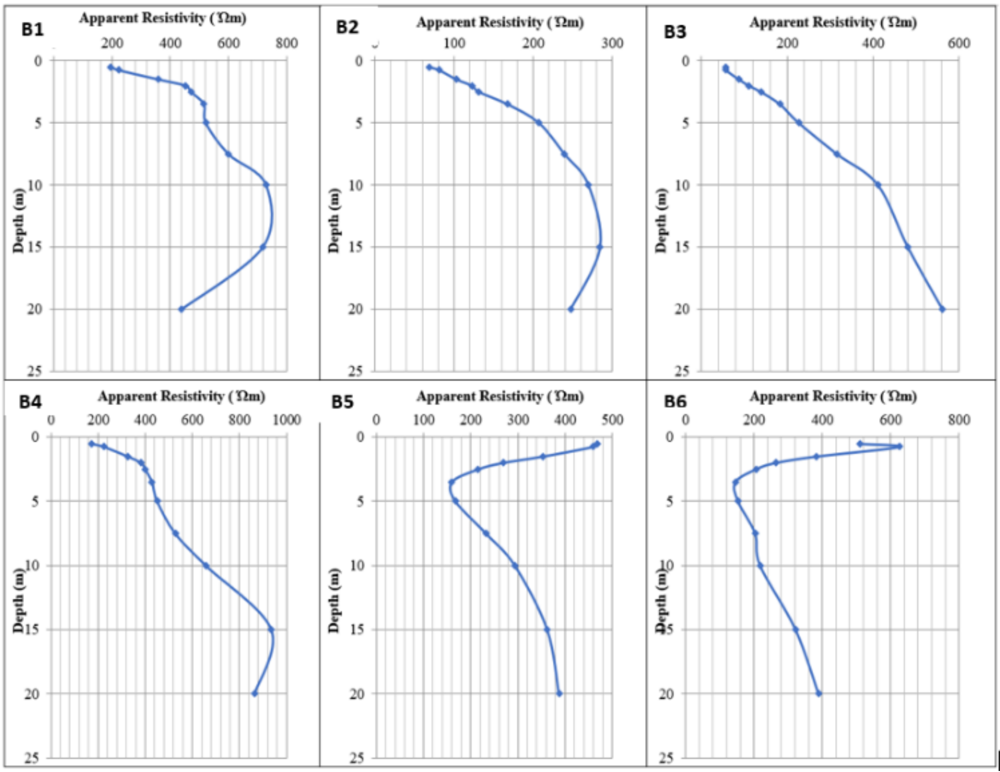

Figure 3: Resu1ts of Measured Apparent Resistivity P1otted against Depth for Survey Conducted in Akpajo Community

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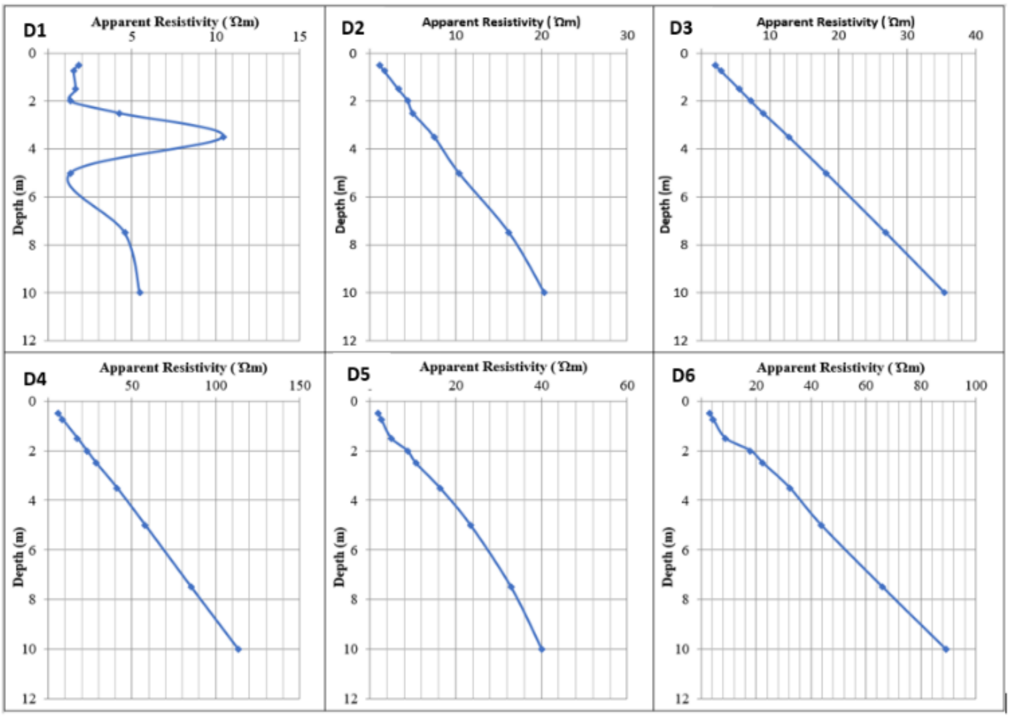

Figure 4: Resu1ts of Measured Apparent Resistivity P1otted against Depth for Survey Conducted in Dutch Is1and Community

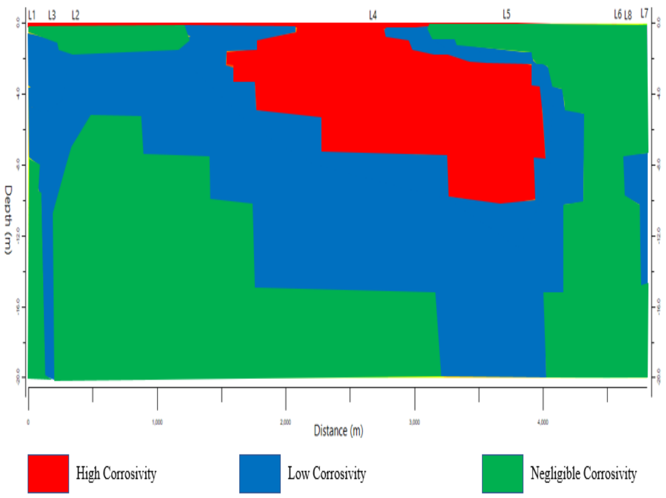

Figure 5: Soil Corrosivity Map in Obirikom

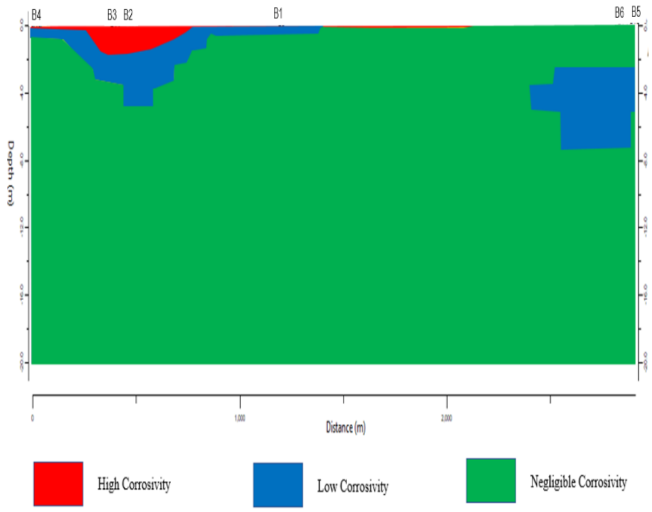

Figure 6: Soil Corrosivity Map in Akpajo

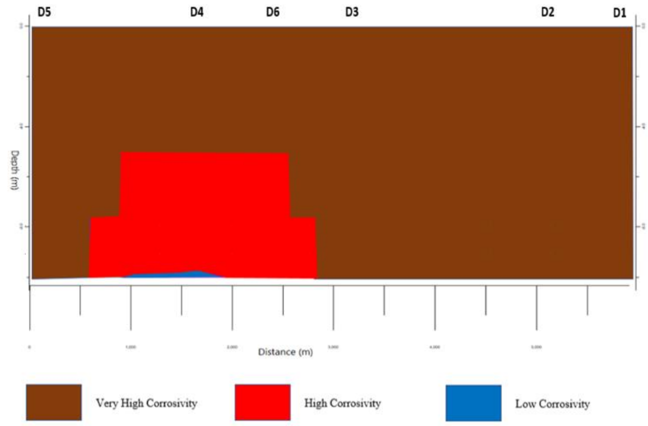

Figure 7: Soil Corrosivity Map in Dutch Island

4.2 Discussion

4.2.1 Soil Corrosivity

Soi1 corrosivity was interpreted based on soi1 corrosivity classification scheme as follows (Abes et al., 1985): <50Ohm.m (Very high corrosive probability), 50-100Ohm.m (High corrosive probability), 100-200Ohm.m (low corrosive probability) and >200 Ohm.m (Negligible Corrosivity). Based on this classification, the soils in Obirikom buried pipeline area range from highly corrosive soils to negligible corrosive soils. Surrounding the highly corrosive soils are soils with low corrosivity and extends to a maximum depth of 20.0m. Similarly, in Akpajo, the soil corrosivity ranges from highly corrosive soils to negligible corrosivity. High corrosivity was encountered only at B2 from the surface to about 1.5 m depth.

A thin layer of low corrosivity was encountered at B1as well as B2. Most of the soils in Akpajo have negligible corrosivity, indicating that the buried pipelines are still in good conditions. The buried pipelines around B2 should be investigated to prevent further corrosion and leakage of the pipeline products. The soils in Dutch Island range from low corrosivity to very high corrosivity. Dutch Island has the most corroded soils. The entire soil layers encountered to a depth of 10.0 m in D1 and D2 are all very highly corrosive. Along D1, the soi1s are very highly corrosive from the surface to a depth of 5.0m and highly corrosive to a depth of 10.0m along D2.

4.2.2 Soil Resistivity

In Obirikom (L1 to L2), the resistivity values obtained range from >40 to <900Ohm.m across the entire area. The lowest resistivity va1ues are centralized around the western part of the survey area in Obirikom. Generally, resistivity in the area increases with depth. In Akpajo (B1 to B2), resistivity values range from <50 to >700 Ohm.m. Also, resistivity increases with depth in Akpajo area with some anomalies at shallow depths which are indicative of pipeline corrosion.

In Dutch Island (D1 to D2), resistivity recorded from the survey are relatively very ranging from >0 to 110Ohm.m, from the surface cutting across the 3m to 10m depth. The flat and swampy characteristic of this area is a factor which has also contributed to the low resistivity values obtained from that area. Similarly, in Dutch Island, the resistivity values in general increases with depth across the entire surveyed area. The lowest resistivity values are centred around the south-western part of the survey area.

4.2.3 Lithology

Soil having high sand content or proportion have a very 1ow storage capacity for water, whereas clay is good at retaining water hence its origin of conducting capacity. In this study, low resistivity values ranging from >0.0Ohm.m to 75.0Ohm.m are interpreted as sandy-clay and si1ty-clay, >75.0Ohm.m to 200Ohm.m are si1ty-sands and sandy-si1t, >200.0Ohm.m to 1000Ohm.m are interpreted as Sands. The lithologic units inferred in Obirikom include sand, silty-sand and sandy-clay. The overlying lithologic unit (<0.5m depth) is occupied by sandy-c1ay which is underlain by silty-sand and subsequently by sands which stretched from <6.0m to 20.0m depth. Generally, sands are the most predominant lithologic unit in Obirikom, closely followed by silty-sand and a minor area is occupied by sandy-c1ay.

This sandy-clay unit is underlain by the silty-sand unit which is underlain by the sand unit. In Akpajo, three lithologic units were inferred from the resistivity measurements and include sand, silty-sand and sandy-c1ay. Both sandy-clay and silty-sand occupies < 30% of the entire surveyed area in Akpajo community. Meanwhile sands occupy over 70% of the entire study area. The sandy lays are the top soils, underlain by silty sand and subsequently sandy soils which extends the entire 20.0 m probed depth. In Dutch Island, two lithologic units were inferred from the resistivity measurements and include silty-clay and sandy-silt. The silty clay occupies a very extensive area and is underlain by sandy-silt. D1 and D2 in Dutch Island recorded only silty-clay soils through the entire 10.0 m thickness.

5. Conclusion

The idea behind this study is to investigate soil corrosivity in underground pipelines in some parts of Rivers State. The approach used to achieve this involved geophysical analysis to identify the resistivity distribution with depth, in terms of the geoelectric layer, corrosivity severity caused by factors characterised by 1ithology of the area. From this study, it is concluded that high corrosivity are indicated by low electrical resistivity and high negative spontaneous potential va1ues. The presence of clay which has the capacity to retain water and the presence of swamp and bog sites in some of the lines on which this study was carried out, made conductivity very high and corrosion of the pipelines to be on the increase. The Wenner configuration is a good technique for this study and gives a picture of the subsurface resistivity distribution which can be used to identify areas of high and low resistivity, thus giving a picture of where corrosion is severe and where it might be negligible.

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