

Geoelectrical Investigation of Underground Pipeline Corrosiveness as a Function of Porosity in Parts of Bayelsa State, Nigeria

Amonicah J and Chukwu C Ben*

Department of Physics, Faculty of Science, Rivers State University, Port Harcourt, Nigeria

ABSTRACT

Underground pipeline corrosiveness as a function of porosity was investigated in parts of Bayelsa State using geoelectrical method. Vertical electrical sounding using Wenner electrode configuration was carried out on eight locations with the aid of Abem terrameter SAS100B. Data acquired were interpreted using IPI2Win software 2020 version. The results of this study showed that apparent resistivity values range from 109.93 – 261.56Ωm for Elebele (L1), 143.51 – 259.68Ωm for Imiringi (L2), 77.54 – 189.84Ωm for Otuasega (L3), 52.25 – 446.82Ωm for Otuoke (L4), 221.75 – 831.60Ωm for Emeyal (L5), 52.83 – 275.19Ωm for Oruma (L6), 148.96 – 952.99Ωm for Otuokpoti (L7) and from 132.32 – 579.33Ωm for Olaibiri (L8) and there is a general decrease in the values of resistance as depth increases for each of the vertical electrical sounding (VES) locations. Due to low resistivity value resulting from high porosity recorded at Otuasega (L3), Imiringi (L2) and Elebele (L1), underground pipelines in these locations are prone to high corrosiveness, whereas underground pipelines located within Otuokpoti (L7), Emeyal (L5) and Olaibiri (L8), will most likely not be affected by corrosion or experience failure or leakage due to high resistivity value resulting from low porosity.

*Corresponding author

Chukwu C Ben, Department of Physics, Faculty of Science, Rivers State University, Port Harcourt, Nigeria.

Received: February 05, 2024; **Accepted:** February 09, 2024; **Published:** July 12, 2024

Keywords: Resistivity, Terrameter, Lithologic, Porosity, Corrosion

Introduction

Geoelectrical investigation or survey involves the detection of surface effects produced by the electric current inside the earth. This technique has gained wide range of geophysical applications such as determination of the depth of water table, location of contaminant plume, damp stability analysis, location of buried pipe, permafrost and geological mapping etc. This is used in the investigation of vertical and horizontal discontinuities in the electrical properties of the subsurface and in the detection of three dimensional bodies of anomalous electrical conductivity. It is routinely used in engineering and hydrological investigations to investigate the shallow subsurface geology [1].

Understanding the effects of corrosion or corrosiveness of buried metallic materials like pipes beneath the surface of the earth is essential as water, hydrocarbon and other fluids are transported through thousands of kilometres of buried pipelines [2]. Corrosion of most common engineering materials at near ambient temperatures occurs in aqueous (water-containing) environments and is electrochemical in nature. The aqueous environment is also referred to as the electrolyte and in the case of underground corrosion, is moist soil. The corrosion process involves the removal of electrons (oxidation) of the metal and the consumption of those electrons by some other reduction reaction, such as oxygen or water reduction.

Corrosion is the degradation of a metallic material or its properties due to its reaction with the environment in which it is immersed [3]. This gradual destruction affects metals, and it is produced

by a chemical or electrochemical reaction with the environment surrounding it [4]. Corrosion remains a threat to underground pipeline due to its reduction both static and cyclic strength of pipes because the soil contains corrosive elements that initiate and accelerate metallic deterioration [5,6].

Porosity is a measure of water storage capacity of soil rocks, it describes of how much space there could be in the soil or rock to hold water or how much water can be stored in geologic materials. Porosity is a fundamental property in rock or soil classifications, it defines the amount of available pore space present in the soil or rock and is represented by the Greek symbol phi (Φ) [7].

Area of Study

The area of study is located in the coastal area of the transitional environment of the recent Niger Delta and lies between within longitude 6.34000E and 6.39000E and latitude 4.60000N and 4.90000N (Figure 1). Physio-graphically, it lies within the saltwater and freshwater swamp geomorphic units of the Niger Delta Sedimentary Basin of Southern Nigeria which is characterized by nearly flat topography sloping very slightly seawards [8]. The swamps are vegetated tidal flats formed by a reticulate pattern of interconnected meandering creeks and tributaries of the River Niger. The delta axis of the area of study is characterized by intense river meandering and consists of silty clay and sands. The flood plains adjoining the major river network become inundated during the peak of the flood. Apart from the main river systems, there are also a series of seasonal streams in the swamps. The area is underlain largely by alluvial and hydromorphic soils and lacustrine sediment of Pleistocene age [9].

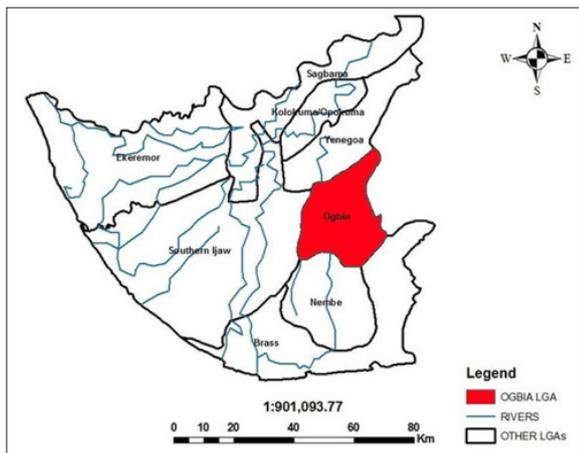


Figure 1: Map of Bayelsa State Showing the Area of Study

Materials and Methods

Materials

Materials used in this study include Abem terrameter SAS 1000B, Global Positioning System (GPS), a pair of current electrode, a pair of potential electrode, measuring tapes, hammer, reels of wires, 12 volts battery, interconnected wires and field data recording sheet.

Method

Field Data Acquisition

The field data set used for this study comprised of data obtained using Wenner electrode configuration of vertical electrical sounding (VES) carried out within the study area using Abem terrameter SAS1000B.

Field Procedure

Wenner electrode configuration was used in the field data acquisition, the electrode were pegged into the ground and are maintained at current-potential electrodes pair distance of $AM = MN = NB = a$, at a fixed point.

Direct current is introduced into the ground from the Abem terrameter signal averaging system (SAS1000B) by means of a pair of current electrode and the resulting potential difference is measured between two properly placed potential electrodes with respect to the current electrodes. The procedure is based on the fact that current penetrates continuously deeper into the ground with increasing electrode spacing, the pairs of electrodes (current and potential electrodes) have a common midpoint as they are

equally spaced along a straight line.

At each measurement, all the four electrodes are symmetrically moved outwards so that the array spacing is increased by steps, and keeping the midpoint of the configuration fixed. The cables were connected from the terrameter to all the electrodes accordingly. Before measurements or readings were taken, the terrameter and the connections were checked to obtain accurate reading for each point. The Abem terrameter SAS 1000B records both the voltage and current simultaneously, pile up the results, computes the resistance in real time and projects it digitally in a display screen. The same procedure was repeated for each location along the marked profile, as the current electrode separation increases the depth of current penetration to the ground also increases.

Results and Discussion

The results of the geo-electrical investigation carried out in the area of study using Wenner electrode configuration of vertical electrical sounding (VES) at eight locations are presented in Tables 1-3 for the various points, whereas Figures 2-4 show the plots of computed apparent resistivity values versus depth of probe for each VES point.

High porosity indicates the presence of pore fluid (fluid in the pore space). As a result of the conductive nature of the pore fluid, resistivity is low, which is an indication of high corrosiveness. Thus, any underground pipeline in this area of low resistivity, will likely experience failure or leakage due to high corrosiveness. From the range of values of apparent resistivity obtained in this study, Otuasega (L3), Imiringi (L2) and Elebele (L1) are in this category, thus underground pipelines in these locations are prone to high corrosiveness.

Low porosity indicates little or absence of pore fluid, as a result, resistivity will be high, which is an indicative of low corrosiveness. Therefore, any underground or buried pipeline in this area of high resistivity will most likely not be affected by corrosion or experience failure or leakage. Otuokpoti (L7), Emeyal (L5) and Olaibiri (L8) are in this category, thus underground pipelines in these locations are free from corrosion.

Oruma (L6) and Otuoke (L4) have moderate range of resistivity values compared to other locations with high or low resistivity values, thus underground pipelines in these locations will experience considerably effect of corrosiveness.

Table 1: Results of Vertical Electrical Sounding (VES) of Elebele (L1)

AB (m)	Electrode Spacing, a (m)	MN/2 (m)	Constant, K	Resistance (Ω)	Apparent Resistivity (Ωm)	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

Table 2: Results of Vertical Electrical Sounding (VES) of Imiringi (L2)

AB (m)	Electrode Spacing, a (m)	MN/2 (m)	Constant, K	Resistance (Ω)	Apparent Resistivity (Ωm)	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

Table 3: Results of Vertical Electrical Sounding (VES) of Otuasega (L3)

AB (m)	Electrode Spacing, a (m)	MN/2 (m)	Constant, K	Resistance (Ω)	Apparent Resistivity (Ωm)	Depth of Probe (m)
1.50	0.50	0.25	3.14	60.46	189.84	0.50
2.25	0.75	0.38	4.71	34.34	161.74	0.75
4.50	1.50	0.75	9.42	11.26	106.07	1.50
6.00	2.00	1.00	12.56	6.75	84.77	2.00
7.50	2.50	1.25	15.70	4.94	77.54	2.50
10.50	3.50	1.75	21.98	3.76	82.73	3.50
15.00	5.00	2.50	31.40	3.25	102.14	5.00
22.50	7.50	3.75	47.10	3.04	143.37	7.50
30.00	10.00	5.00	62.80	2.48	155.56	10.00

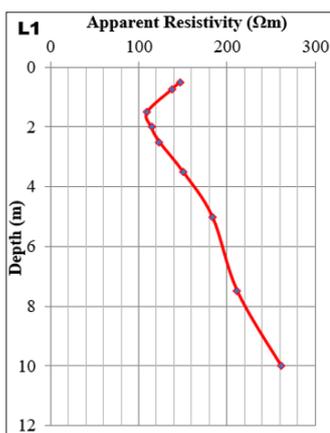


Figure 2: Plot of Apparent Resistivity Versus Depth for Elebele



Figure 3: Plot of Apparent Resistivity versus Depth for Imiringi

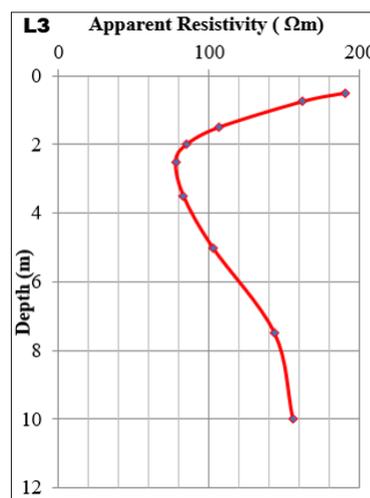


Figure 4: Plot of Apparent Resistivity Versus Depth for Otuasega

Conclusion

Resistivity influences the corrosion of underground pipelines and can serve as an indicator of soil corrosiveness. The effect is expected to be more severe in areas dominated by mangrove plants because of the influence of saline water. Base on the results obtained from this study, the following conclusions are drawn:

- High porosity is an indicative of high corrosiveness due to the presence of low resistivity pore fluid.
- Low porosity is an indicative of low corrosiveness due to the presence of high resistivity pore fluid.
- Underground pipeline within Otuasega (L3), Imiringi (L2) and Elebele (L1) locations are more prone to corrosiveness due to the low range of values of apparent resistivity.

- Underground pipeline within Otuokpoti (L7), Emeyal (L5) and Olaibiri (L8) locations are less prone to corrosiveness due to the high range of apparent resistivity values.
- There is observance of linearity in apparent resistivity with depth in Elebele (L1), Imiringi (L2) and Oruma (L6) vertical electrical sounding locations.

References

1. Kearey P, Brooks M, Hill I (2002) *An Introduction to Geophysical Exploration*. Third Edition Blackwell Science Ltd 184-190.
2. Kirmeyer GJ, Richards W, Smith CD (1994) *An assessment of the Water Distribution System and Associated Research Needs*. American Water Works Research Foundation, Denver.
3. Schmitt G (2009) *Global Needs for Knowledge Dissemination, Research, and Development in Materials Deterioration and Corrosion Control*; World Corrosion Organization: New York, NY, USA.
4. AIter LB, Maestres FL (2004) *Corrosion and Protection*; Polytechnic University of Catalonia: Barcelona, Spain, 150.
5. Abes AJ, Salinas JJ, Rogers J (1985) *Risk Assessment Methodology for Pipeline Systems*. *Structural Safety* 2: 225-237.
6. Cosham A, Hopkins P (2003) *The Assessment of Corrosion in Pipelines—Guidance in the Pipeline Defect Assessment Manual (Pdam)*. International Colloquium Reliability of High Pressure Steel Pipelines 1-30.
7. Tiab D, Donaldson EC (2004) *Petrophysics: Theory and Practice of Measuring Reservoir Rock and Fluid Transport*. Second Edition Gulf Professional Publishing, USA.
8. Etu-Efeotor JO, Akpokodje EG (1991) *Aquifer systems of the Niger Delta*. *Nigerian Journal of mining Geology* 26: 279-284.
9. Osakuni MU, Abam TKS (2004) *Shallow Resistivity Measurement for Cathodic Protection of Pipeline, in the Niger Delta*. *Environmental Geology* 45: 747-752.

Copyright: ©2024 Chukwu C Ben. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.