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Research Article

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Determination of Corrosive Soils along Brass-Obama Pipeline Route, South-South Nigeria Using Electrical Resistivity Method

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Abstract Eighteen vertical electrical sounding (VES) were carried out using ABEM SAS 300B Terrameter along Brass-Obama pipeline route, in the Niger Delta Region of Nigeria. The aim was to determine the resistivity and nature/thickness of the different subsurface layers and to infer the corrosivity of the soils along this proposed pipeline route. The Schlumberger array configuration was adopted for the study with current electrode separation between 3 and 45 m with the assumption that the depth of penetration with respect to spread is about one-fifth of the separation. Measurements were taken in both N-S and E-W directions. The field data were analyzed using software IP12Win to obtain the formation resistivities, and geoelectric sections/depths. The results gave geoelectric sections with varying resistivity values ranging from 0.27 Ωm to 17 Ωm along the profile. The overburden thickness of the sub-soil ranged from 0.7 m to 21.7 m. The VES curve depicts low resistivities along the pipeline route except from a few kilometers away from Brass terminal where the resistivity value was relatively high. The low resistivities are within the accepted standard range of 1 to 100 Ωm for soils classified as corrosive soils. This low resistivity values are due to the influence of saline water in the area and any underground metallic piping along this proposed pipeline route would be subjected to corrosion.

Keywords Electrical Resistivity, Corrosivity, Niger Delta, Subsurface Soils

1. Introduction

Pipelines are mostly used to transport hydrocarbon and its products in most parts of the world; either on the earth's surface or subsurface and a common form of structural degradation that reduces both the static and cyclic strength of a pipeline is corrosion [1]. It represents a significant proportion of the cause of failures of natural gas pipelines and is recognized as one of the most dominant forms of deterioration process for offshore steel pipelines [2]. According to [3] has identified factors causing corrosion in soils as moisture content, soil resistivity, pH, dissolved oxygen, temperature and microbial activity. The same authors indicate that corrosion rates of buried pipes are inversely proportional to soil resistivity. Soils containing more organic matter and saline water show high resistivity.

The type of electrical circuitry which sustains corrosion processes in soils harboring pipelines according to [4],[5] and [6], is a function of differing soil properties along the route of the pipeline; relationship of the pipes to other metallic objects in the same soil and the type of metal used in the connections on the pipe route. This flow of electricity is associated with an electrochemical process, which can cause corrosion effects, such as rusting of the metallic surface that is carrying the electrical current. The flow of electricity being discharged from one metallic surface, the anode, is completed by the passage of the current from the electrolyte, in this case the soil, to the same or other metal objects nearby, the cathode. The total amount of rusted metal removed from the pipe in the corrosion process is directly related to the amount of electricity flowing in the completed circuit.

Deterioration of buried metal pipes resulting from corrosive soil environment is a major issue worldwide and protection techniques adopted do not completely eliminate this process. One available option to tackle this problem is to avoid corrosive soils when laying pipelines. Corrosive soils can be determined in several ways as shown by [3] and [6]. In this paper the electrical resistivity method was carried out to determine the subsoil resistivity and infer the corrosivity of soils along a pipeline route from Brass to Obama in the Niger delta region which is south-south of Nigeria.

2. Location of Study Area

All the study area is located in the southern Niger Delta Basin of Nigeria (Fig.1). It is a basin of thick accumulation of the Tertiary delta sediment deposited at the southern part of the Benue Trough of Nigeria [7]. This deltaic region is composed of three major depositional environments, the Benin, Agbada and Akata Formations [8].

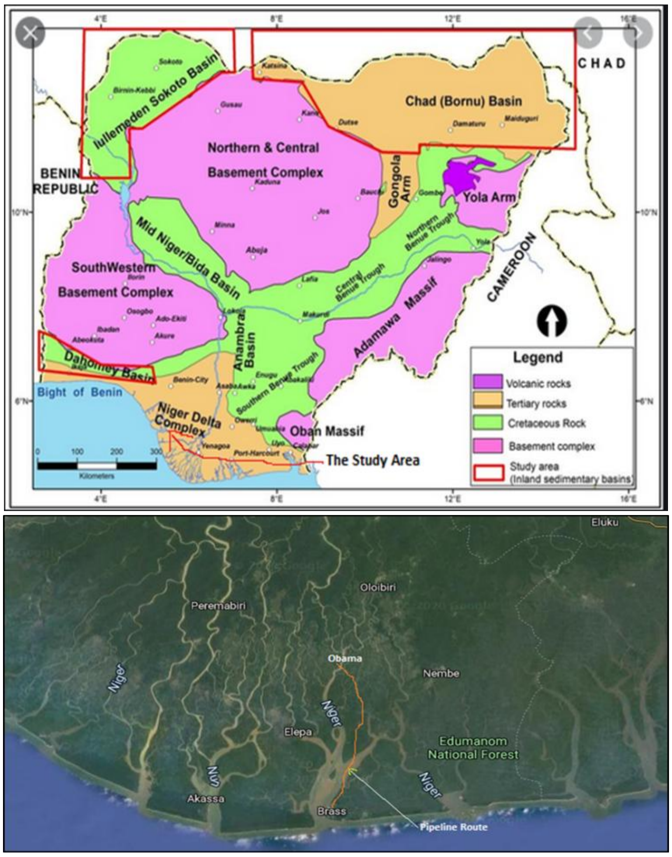

Figure 1: The Study Area (Modified from [9])

A lot has been written about the Niger delta with all showing that it is composed of regressive clastic sequence with sediment deposits of 9,000 to 12,000 m thickness in the central part of the basin. According to [10], the Benin Formation is the uppermost sediment consisting mainly of fresh water-bearing massive continental sands and gravels and back swamp deposits accumulated in an upper deltaic plain environment or continental fluvial environment. The formation is believed to also contain a few shaly intercalations that increase towards the base. The sands and sandstones are coarse to fine grained and are granular in texture. The sands are poorly sorted and partly unconsolidated making it the habitat of aquifers in the region.

The Oligocene Benin Formation according to [11] is underlain by the Eocene Agbada Formation which is a paralic sequence of sandstone and shale. It consists of alternation of sands, sandstones, siltstone and shales and acts as a reservoir or petroleum bearing zone for hydrocarbon accumulation in the region. The Paleocene Akata Formation is the last formation and is composed of thick shales, turbidite sands, and small amounts of silt and clay. This formation is the petroleum source bed of the region [12].

The study area is located in Bayelsa State of Nigeria. The Brass to Obama pipeline route is approximately 39 km in length. The first part of the line passes through predominantly mangrove plant terrain except some few kilometers from Brass terminal, which are dominated by relatively thick vegetation. It traverses through River Brass and many creeks.

3. Materials and Methods

The equipment used for this investigation include an ABEM SAS 300B Resistivity Meter model with a dry battery unit capable of voltage outputs from 50-400 volts DC, steel electrodes, and lightweight and all accessories. The Schlumberger array was used because of its operational convenience, ability to obtain reliable data and high vertical resolution. Generally for a VES the depth to which current penetrates the ground is proportional to the current electrode spacing. Reynolds [13] shows that the apparent resistivities, ρ_a, of the formations are proportional to the product of the earth resistance, *R*, and geometric factors of the electrode configurations. For the Schlumberger array used, the apparent resistivity was obtained from the relationship

$$\rho_a = \frac{\pi a^2}{b}[1 - \frac{b^2}{4a^2}]R \qquad 1.$$

Where *a* is half the current electrode spacing and *b*, half the potential electrode spacing.
Measurements were conducted along the profile at specified intervals with current electrodes separations of 3, 4.5, 6, 9, 12, 15, 21, 30 and 45 respectively. Measurements were taken in north-south and east-west directions with a view to determining any major variation(s) in the soil resistivity. Also, the mean value of the measured apparent resistivity along the N-S, E-W directions was computed for each test point and plotted on log-log values of half the current and electrode spacing to obtain the field curves. This was interpreted using IPWIN2 software to obtain the results summarized in Fig. 2 and Table 1.

4. Results and Discussion

The apparent resistivity values obtained from the field were plotted against half current electrodes spacing on a log-log scale. The initial values of the thickness and resistivities of the geoelectric layers encountered within the depth of investigations were obtained. These values were used as the initial model parameters in IP12Win software to obtain a fit to the field data. The layer parameters, the true resistivity and thickness as revealed by the field curve lines along the eighteen profiles (Fig. 2) are shown in Table 1.

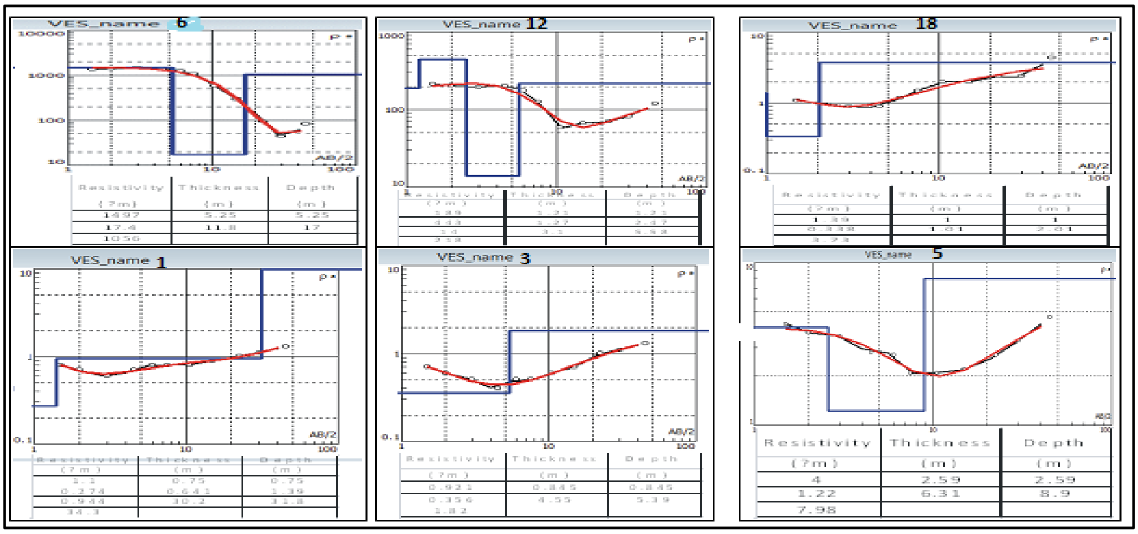

Figure 2: Field curve lines of different points along the pipeline route.

Table 1: Geoelectric Layer Thickness and Resistivities of the Brass-Obama Pipeline Route.

VES	Layer thickness (m)			Total depth	Resistivity (Ωm)			
Points	1	2	3	(m)	1	2	3	4
1	5.25	11.8	-	**17.0**	1497	17.4	105	-
2	0.93	3.55	-	**4.48**	1059	109	35.5	-
3	1.21	1.27	3.10	**5.58**	189	443	14	218
4	1.74	2.69	-	**4.43**	2.91	0.48	234	-
5	1.0	1.01	-	**2.01**	1.39	0.338	3.73	-
6	0.75	8.14	-	**8.89**	2.03	0.82	2.11	-
7	8.90	21.70	-	**30.6**	0.75	1.40	2.1	-
8	0.75	13.90	-	**14.6**	2.74	0.90	180	-
9	0.90	4.2	-	**5.10**	0.88	0.3	1.40	-
10	0.70	1.20	-	**1.90**	3.91	0.4	113	
11	2.45	1.20	-	**4.74**	1.05	0.43	102	-
12	0.85	4.55	-	**5.40**	0.92	0.36	1.82	-
13	1.0	2.70	-	**3.70**	131	14.0	3.22	
14	0.89	0.80	40.7	**42.4**	13.9	2.83	11.2	786
15	2.59	6.31	-	**8.90**	4.0	1.22	7.98	-
16	1.1	10.5	-	**11.6**	1.34	2.10	2.13	-
17	1.48	1..78	-	**3.26**	0.80	0.27	3.93	-
18	0.75	0.64	30.2	**31.8**	1.1	0.27	0.94	34.3

Table 1 depicts the apparent resistivity distribution of the layers for representative tested points. Apart from few high values observed towards Brass terminal (points 2 and 3), the apparent resistivity values are generally low. This can be attributed to the influence of saline water in this region. The subsoil resistivity values for the test points show similar trend with high values towards Brass terminal and extremely low values towards Obama flow station. The resistivity values range between 0.27 to 17Ωm. It is worth noting to say that mangrove plants dominate such areas. The field curves are dominantly type-H curves with thickness of the subsoil layers between 0.7 to 21.70 m. The maximum depth penetrated within pipe-laying depth falls between 1.90 to 30.6 m.

Using the British Standard BS-1377 [14] for evaluating corrosion that places corrosive soils as those below 50 Ωm, we see that the topsoil layers are highly corrosive compared to other layers with high resistivities which are not corrosive. Generally, the sub-soil condition along Brass-Obama pipeline route is very aggressive and severely corrosive for pipe laying. This area is close to the sea and intrusive saline waters may have affected the subsurface soils making them to be conductive. Therefore, it must be noted that piping structures installed along the proposed pipeline routes would be subjected to corrosion. The effect is expected to be more severe in areas dominated by mangrove plants because of the influence of saline water. Proper coating and protection is therefore recommended before lying of the pipes along the route.

5. Conclusion

This study has shown that most layers of soils along the Brass-Obama proposed pipeline route have low resistivity values that fall within the range of corrosive soils. Pipelines along this route should be properly coated to minimize the effect of corrosion on them and to avoid frequent hazards associated with ruptured pipelines.

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