Application Of Geo-Resistivity In Soil Corrosivity Rating To Aid Cathodic Protection Plan for Underground Oil and Gas Utilities In Elelenwo Area of Rivers State, Nigeria.

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Abstract— Geo-resistivity method was applied in soil corrosivity rating to aid cathodic protection plan for underground oil and gas utilities in Elelenwo area of Rivers State, Nigeria. Underground utilities in the study area are affected by corrosion due to variations in soil pH, resistivity, dissolved oxygen, anions, bacterial content and poor drainage condition of the environment. The soil is generally lateritic sandstones with varying amounts of sand, silt and clay. The geo-resistivity values obtained within the study area show that at less than four meters depth, the soil corrosivity increases with depth, and ranges from 1.086Ωm to 390.480Ωm, indicating extremely corrosive to essentially non-corrosive soils, respectively. The results indicate that corrosion control measures should be applied on underground utilities in the area based on utility depth of burial. The adopted cathodic protection design should aim at enhancing conditions that prevent corrosion based on the soil corrosivity rating for study area.

Index Terms— Corrosivity, reisistivity, cathodic protection, underground Utilities, Wenner array, soil, environment

1 Introduction

Corrosion is the deterioration of a material, usually a metal due to its reaction with the environment [1]. Corrosion is a problem and cathodic protection (CP) is the dominant method used to controls its effect on metal surfaces by making it the cathode of an electrochemical cell. Other methods include plastic wrapping to prevent contact and metal replacement with corrosion resistant materials such as asbestos cement. Corrosion could occur externally or internally.

Cathodic protection systems are used to protect metallic structures such as steel pier piles, fuel pipelines, storage tanks, ships, offshore platforms, onshore oil well and metal reinforcement bars for engineering purposes. Cathodic protection is basically divided into two types, namely Galvanic (Sacrificial anode) CP and Impressed Current CP. The choice of grounded type and size of cathodic protection to utilise depends on the application, location and soil aggressiveness.

[2] and [3] stated that buried underground utilities suffer from corrosion due to the interplay between the following soil conditions: (a) High moisture content (b) pH value less than 4.5. (c) Low resistivity. (d) Presence of chlorides, sulphides, dissolved oxygen and bacteria (e) Presence of stray currents. (f) Poor drainage. The above mentioned factors can be seasonal. For example, soil resistivity generally decreases as temperature increases while poor drainage impact is felt dominantly during the rainy season.

This study encompasses the use of soil electrical resistivity values to infer its level of corrosiveness in order to aid cathodic protection design in Elelenwo Area.

2 Methology

Soil resistance was measured using a resistivity meter with an accurate calibration and Wenner configuration was utilised based on [4]. In this configuration, the potentials (P1 and P2) and current (C1 and C2) electrodes have a common mid-point and the distances between adjacent electrodes are equal [5]. The soil resistivity was computed from the resistance values obtained the using equation below.

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$$\rho = 2\pi a R \quad (1)$$

Where "ϱ" is Resistivity, "a" is Potential electrode spacing and "R" is Resistance [5].

Fig. 1: Resistivity Kit

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Generally, an increase in the current electrode spacing implies an increase in the depth evaluated from the surface.

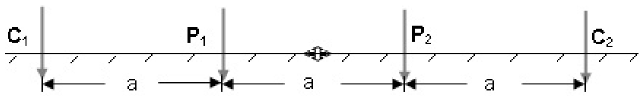

Fig. 2: Wenner Configuration (= Common Mid-Point)

[6] resistivity classification scheme (Table 1) is applied to classify soil corrosiveness based on resistivity values obtained.

TABLE 1

[6], Soil Corrosivity Classification Scheme

Soil Resistivity (Ωm)	Corrosivity Rating
>200	Essentially non-corrosive
100 – 200	Mildly corrosive
50 – 100	Moderately corrosive
30 – 50	Corrosive
10 – 30	Highly corrosive
<10	Extremely corrosive

3 STUDY AREA

The study location is Elelenwo in Obio Akpor Local Government Area of Rivers State. In the study area, the heaviest precipitation occurs during September with an average rainfall of 370 mm, while December on average is the driest month of the year with an average rainfall of 20 mm.

The average temperature is typically between 25°C and 28°C, while the relief ranges from low to moderate. The study area is an industrial zone with a few settlements.

4 RESULTS AND DISCUSSION

Table 2 shows the geo-resistivity values obtained within study area using Wenner array configuration.

The results show geo-resistivity range of 1.086 to 390.48Ωm indicating extremely corrosive to essentially non-corrosive soils. The soil corrosiveness varies with location and depth.

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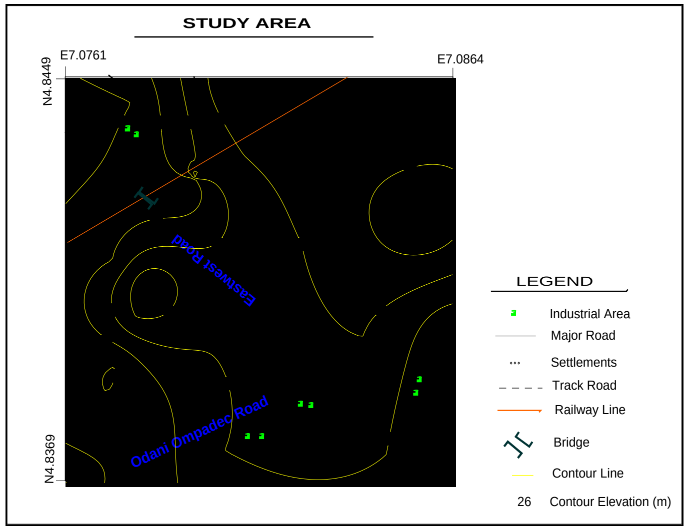

Fig. 3: Location and Topographic Map of the Study Area.

High soil corrosiveness is a dominant attribute of the relatively low relief zones within the study areas. Generally, the degree of soil corrosiveness increases laterally with depth (<4m).

TABLE 2

Geo-Resistivity Values Obtained Using Wenner Array Configuration (a = electrode Spacing; ρ = Resistivity; h = Elevation).

Eastings	Northings	Elevation (m)	Electrode spacing (m)	Resistivity (Ωm)
E7°5'5"	N4°51'39"	23	0.5	75.69
			1	64.18
			2	42.97
			3	20.79
			5	16.48
E7°5'8"	N4°51'31"	21	0.5	160.51
			1	8.872
			2	3.463
			3	5.93
			5	52.61
E7°5'2"	N4°50'23"	23	0.5	60.72
			1	54.81
			2	42.84
			3	33.65
			5	23.59
E7°5'5"	N4°50'15"	24	0.5	223.5
			1	186.5
			2	109.3
			3	66.08
			5	40.83
E7°4'57"	N4°50'30"	23	0.5	129.5
			1	72.61
			2	28.42
			3	4.879
			5	5.016
E7°4'51"	N4°50'36"	23	0.5	342.9
			1	290.2
			2	118.2
			3	60.39
			5	7.264
E7°4'49"	N4°50'15"	24	0.5	200.6
			1	97.06
			2	40.84
			3	25.16
			5	12.16
E7°4'48"	N4°50'25"	24	0.5	100.1
			1	118.1
			2	69.83
			3	40.84
			5	36.35
E7°4'40"	N4°50'40"	26	0.5	249.6
			1	168.9
			2	90.67
			3	60.19
			5	42.65
E7°4'38"	N4°50'29"	25	0.5	3.486
			1	1.806
			2	66.65
			3	55.06
			5	48.12
E7°4'40"	N4°50'17"	26	0.5	390.48
			1	260.8
			2	90.22
			3	44.66
			5	5.082

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The decreasing soil resistivity values is attributed to increasing moisture content and variation in sand-silt-clay content within depths less than four meters (4m).

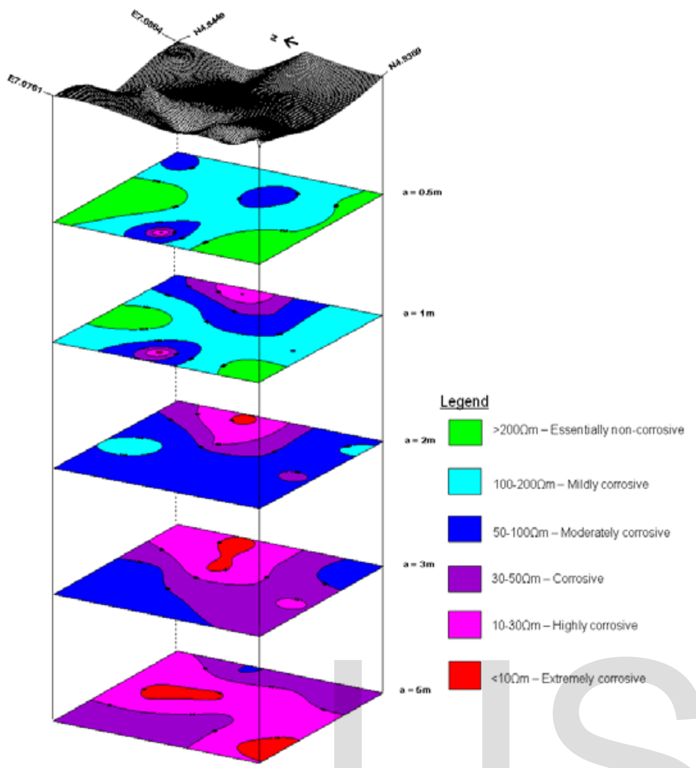

Figure 4: Soil Corrosivity Rating Base on Geo-resistivity Values (a=Electrode Spacing) within Longitudes E7.0761 ($E7^0 4'34''$) and E7.0864 ($E7^0 5'11''$) and Latitude N4.8449 ($N4^0 50'42''$) and N4.8369 ($N4^0 50'13''$).

The geo-resistivity values are used to produce contour maps (Figure 4) based on [6]) soil corrosivity classification scheme. The contour maps are then correlated to a 3D wireframe topography model of the area.

Corrosion control is achievable by pH adjustment, application of chemical inhibitors and electrochemical measures (Galvanic CP) which are designed so that conditions that encourage corrosion are avoided. Application of controls is dependent on soil aggressiveness which varies with location and proposed burial depth of utilities.

5 CONCLUSION

Soil investigation by geo-resistivity method was carried out as an aid to cathodic protection design for corrosion prevention of underground utility in the Elelenwo area. The [6] soil corrosivity classification scheme was applied in predicting "corrosive" soils based on soil electrical resistivity values obtained at site using Wenner array electrical configuration.

Generally, the investigation indicates that the soil aggressiveness within study area ranges from extremely corrosive to essentially non-corrosive. The extent of soil corrosivity varies with location and depth. Corrosion control is to be applied based on the degree of soil aggressiveness and cathodic protection should be designed to discourage any factor that enhances corrosion.

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