EVALUATION OF SOIL CORROSIVITY USING ELECTRICAL RESISTIVITY METHOD: A CASE STUDY OF PART OF THE UNIVERSITY OF JOS PERMANENT SITE.

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Abstract: Soil resistivity could be influenced by soil moisture and concentrations of ionic soluble salts which is invariably regarded as the most comprehensive indicator of soil corrosivity. Soil corrosivity is a major concern, especially for buried infrastructure that is aging. Also, environmental protection policies now place emphasis on corrosion related issues. In view of this, the electrical resistivity of the soil of the study area were obtained to determine the corrosivity of the soil and its suitability for laying of pipes and other metals. The soil resistivity values were measured using the Wenner's electrode configuration method. The results showed that profile 1 has resistivity ranging from 60.64 to 707.00 Ωm which indicates a practically non-corrosive to slightly corrosive potential and composed of sandy-clay to clayey sand materials. However, profile 2 has a lower resistivity ranging from 13.13 to 95.36 Ωm indicating a moderately corrosive to slightly corrosive tendencies and could be clayey in composition. Profile 4 has resistivity values ranging from 8.55 to 199.16 Ωm which reveals that the soil has a tendency to be either moderately, slightly, strongly or practically non-corrosive and this could be because of the presence of clay materials as well as nonuniformity in the composition of the soil types in this area. On the other hand, Profile 4 resistivity ranges from 15.35 to 127.31 Ωm which shows a moderately corrosive to slightly corrosive tendencies and characterized by clayey to sandy clay soils. The study area could be regarded as potentially noncorrosive, moderately corrosive and slightly corrosive.

Key words – Resistivity, Soil Corrosivity, Clay, Sandy-clay, Corrosity

I. INTRODUCTION

For soils, corrosivity may be defined in terms of soil's ability to corrode a material that may be buried in it. Idornigie [5] stressed the importance of mandatory testing of soil aggressiveness (corrosivity) before building foundations and pipes are laid or buried into the soil. The corrosivity of soil may depend on its mineralogical composition and/or its structure (Agunloye, [1]). Soil corrosive potential could be influenced by the geology of the area where the soil originates and/or anthropogenic activities.

Chemical analysis of soils alone is usually limited in determining the soluble constituents in water under standardized conditions. Therefore, only the base-forming elements, such as sodium, potassium, calcium, and magnesium as well as acid-forming elements, such as carbonate, bicarbonate, chloride, nitrate, and sulfate are determined (Oyinkanola et al.[9]) . Oyubu [7] stated that based on experimental evidences, extremely high alkalinity lowers soil resistivity and increases soil corrosivity whereas mild alkalinity withstand corrosion for a long time. According to him, soils with pH of 5 (acidic) or below can lead to extreme corrosion rate and pitting of metallic objects. A neutral pH of about 7 is most desirable to minimize the potential for damage to earthing structures. Also, Olayinkanola et al. [9] reported that, fine-grained soils such as clays and some silts are considered to have a greater corrosion potential because they typically have lower hydraulic conductivity resulting from the accumulation of acid and base forming materials which cannot be leached out very quickly. However, they stated that granular soils such as sands and gravels are considered to have a reduced corrosion potential because of increased hydraulic conductivity resulting in the leaching of accumulated salts. They further suggested that, as a rule, soils with high moisture content, high electrical conductivity, low resistivity, high acidity, and high dissolved-salt content will be most corrosive (Alhazzaa, [2], Paillet [8]).

Moisture content has a profound effect on resistivity, so soils that are completely free of water have extremely high resistivity. Backfill materials will generally be more corrosive than native earth because the backfill soil has higher moisture content. In addition, backfill materials typically never reconsolidate back to the same degree as native soil, allowing more penetration and retention of water

Therefore, this research seeks to evaluate the corrosion potential of soil around the permanent site of University of Jos using the electrical resistivity properties obtained from the area. Result from this study is expected to provide insight into the soils potentially corrosive areas around the measurement points at different depth levels.

II. GEOLOGY AND PHYSIOGRAPHY OF THE STUDY AREA

The geology of the area of study is shown in Figure 1.The aplo-pegmatitic granite gneiss predominates in the area. It is wide spread and occurred as crosscutting sheets with irregular shape.

The Neil's Valley granite porphyry which is part of the Younger Granite Ring Complexes that intruded into the basement. It occurs as massive pluton with relief as high as 1100m above sea level, which is typical of the Younger Granites. It covers the northeastern section of the map of the study area. The rock forms Highlands and concentric intrusions typical of the Younger Granite Ring Complexes.

The Jos type biotite granite occupies the eastern and southeastern section of the map of the study area. The outcrop form large massif covering several hundred meters in size. The rock is mostly medium to coarse grained and have been affected by weathering along the joint planes thus breaking the rock into large boulders. The prominent hilly features in the study area are inselbergs and whalebacks which belong to the category of residual hills commonly associated with massive granite bodies (McCurry, [6]).

The area is drained by River Dilimi and its tributaries which cut across the basement areas in Barkin Rusau, Naraguta and Sabon Layi. The drainage is tectonically controlled as it is seen by its parallelism with the dominant N-S structures of the host rocks.

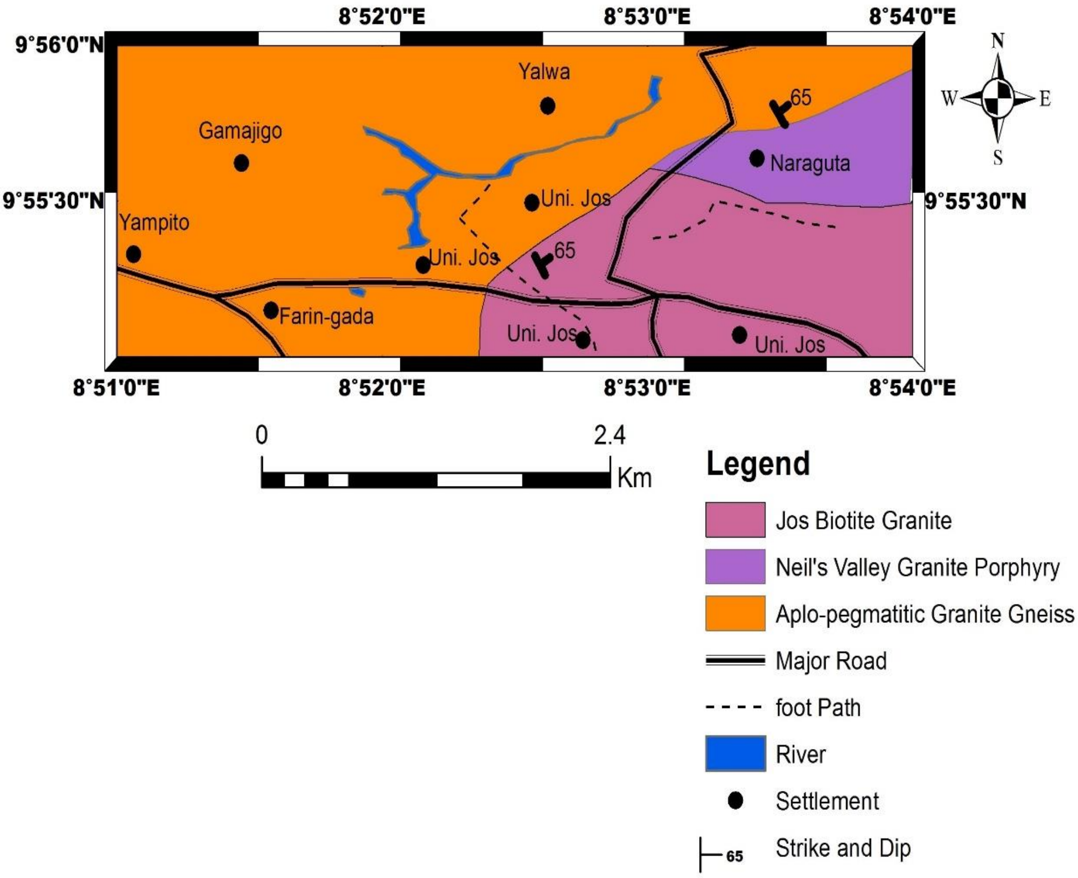

Figure 1: Geology of the study area.

III. METHOD OF STUDY

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The Wenner array method was used to determine the soil resistivity. This method utilizes two current electrodes from which current is passed into the ground and two potential electrodes which measures the potential difference between the two points. A total of 124 points were occupied from where four profiles were formed. For the resistivity to be effectively measured, the four electrodes were firmly inserted into the ground on a straight line and equally spaced (Fig. 2).

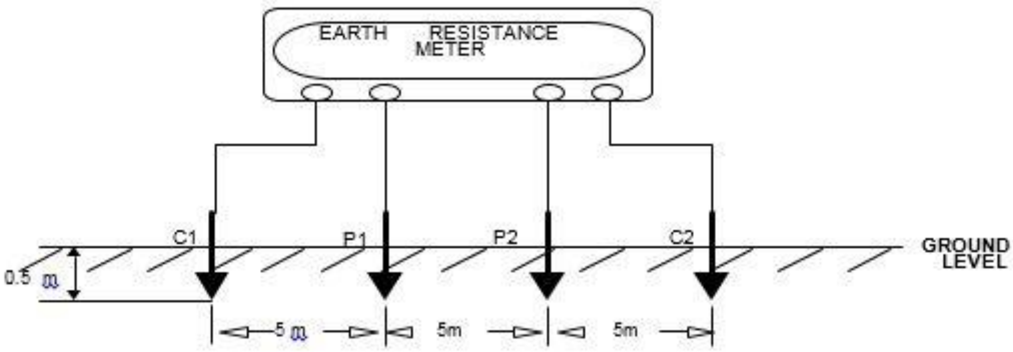

Fig. 2: A simple Wenner electrode configuration

The current electrodes are marked C1 and C2 while the potential electrodes are marked P1 and P2 and spaced at an equidistance of 5m with a depth of penetration of 0.5m.The resistivity measurement were carried out by injecting current (**I**) through the two current electrodes (C1 and C2) into the ground and recording the corresponding results of the potential difference (**V**) at the two electrodes (P1 and P2).

Ohm's law was then applied to calculate the apparent resistance: **R**=**V**/ **I**. However, in this case the resistivity meter used (Allied Omega ABEM SAS 4000 Terrameter) automatically generated the apparent resistivity.

IV. RESULTS AND DISCUSSION

The resistivity values obtained were correlated with soil resistivity values as proposed by Baeckmann and Schenwenk, [3] and assessed based on their competence rating as proposed by Bayowa and Olayowola, [4].

Table 1: Soil Resistivity and its Corresponding Corrosivity based on Baeckmann and Schenwenk, [3]

Soil resistivity (Ωm)	Soil corrosivity
< 10	Very strongly corrosive (VSC)
10–60	Moderately corrosive (MC)
60–180	Slightly corrosive (SC)
>180	Practically non corrosive (PNC)

Table 2**:** Soil Competence Rating based on Bayowa and Olayiwola, [4].

Apparent Resistivity (Ωm)	Lithology	Competence Rating
<100	Clay	Incompetent
100-350	Sandy clay	Moderately Competent
350-750	Clayey sand	Competent
>750	Sand/Laterite/Bedrock	Highly Competent

A. Profile One: Behind Chapel of Faith

This profile has a total of 21 stations with various values of resistivity. Table 3 and fig. 3, indicate that the area generally has a high resistivity values with the highest value at station 14 (706.996 Ωm). However, station 15 has the lowest resistivity value of 60.6356 Ωm. Therefore, based on Baeckmann and Schenwenk [3] and Bayowa and Olayiwola [4], the corrosivity rating of this area is Practically Non-corrosive and it is characteristically sandy-clay to clayey- sand materials which can be rated as

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moderately competent to competent strata while station 15 can be said to be Slightly Corrosive and composed of clay materials which is an incompetent material to construct on, based on the resistivity values given on Tables 1 and 2.

Table 3: Summary of Resistivity Values and Corrosivity Rating of Profile 1

P1	NORTHINGS	EASTINGS	RESISTANCE	$2\pi aR$	CORROSIVITY
1	10.03333	9.003889	16.83	423.4428	Practically non-corrosive
2	10.03250	9.003611	18.81	473.2596	Practically non-corrosive
3	10.03167	9.003333	12.69	319.2804	Practically non-corrosive
4	10.03111	9.003333	10.59	266.4444	Practically non-corrosive
5	10.03056	8.991944	17.33	436.0228	Practically non-corrosive
6	10.03000	9.002778	12.66	318.5256	Practically non-corrosive
7	10.02917	9.002778	9.50	239.0200	Practically non-corrosive
8	10.02833	9.002778	15.97	401.8052	Practically non-corrosive
9	10.02778	9.002500	16.54	416.1464	Practically non-corrosive
10	10.02694	9.001944	19.57	492.3812	Practically non-corrosive
11	10.02614	9.001667	12.17	306.1972	Practically non-corrosive
12	10.02556	9.001111	19.32	486.0912	Practically non-corrosive
13	10.02472	9.000833	22.80	573.6480	Practically non-corrosive
14	10.02389	9.000278	28.10	706.9960	Practically non-corrosive
15	10.02333	9.000000	2.41	60.6356	Slightly corrosive
16	10.0225	8.999722	22.80	573.648	Practically non-corrosive
17	10.03333	8.999444	15.64	393.5024	Practically non-corrosive
18	10.0325	8.999167	9.59	241.2844	Practically non-corrosive
19	10.03167	8.999167	8.34	209.8344	Practically non-corrosive
20	10.03111	8.998889	9.28	233.4848	Practically non-corrosive
21	10.03056	8.999167	7.37	185.4292	Practically non-corrosive

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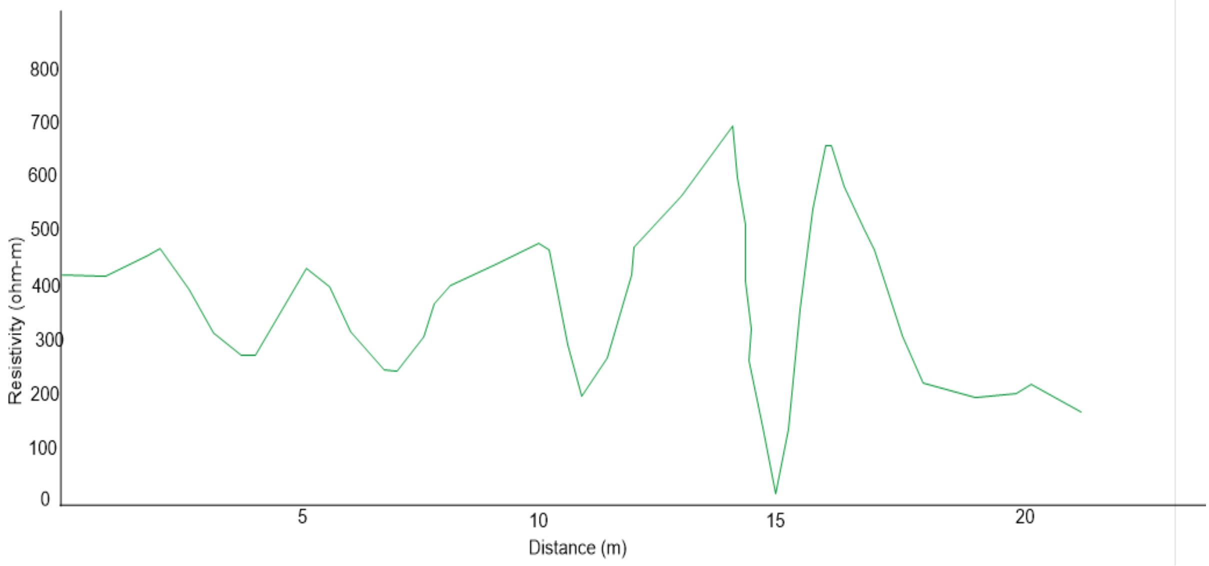

Fig. 3**:** Graph of Resistivity against Distance showing the Corrosivity of Profile 1 in the study area.

B. Profile Two: Naraguta Hostels

This profile has a total of 33 stations showing variations in the resistivity values. The resistivity Values of this profile generally ranges from low to intermediate as shown in Table 4 and plotted in Fig. 4. The highest resistivity value of 95.3564 Ωm was recorded at station 1 and the lowest resistivity value of 13.13352 Ωm was recorded at station 29.

Also, the resistivity values obtained from this survey was compared with the standard proposed by Baeckmann and Schenwenk [3]. The result indicates that the profile is generally Moderately Corrosive with only six stations representing about 18 percent of the profile is said to be Slightly Corrosive. Therefore, from the resistivity values obtained in the profile, it can be suggested that the profile is generally made up of clayey soil. Hence, its ability to retain water within its pore spaces and also lower the resistivity of the soil.

Table 4: Summary of Resistivity Values and Corrosivity Rating of Profile 2

P2	NORTHINGS	EASTINGS	RESISTANCE	$2\pi aR$	CORROSIVITY
1	10.11056	8.956111	3.79	95.3564	Slightly corrosive
2	10.12889	8.956389	2.88	72.4608	Slightly corrosive
3	10.12778	8.956667	1.93	48.5588	Moderately corrosive
4	10.12917	8.956944	1.98	49.8168	Moderately corrosive
5	9.966944	8.957222	3.27	82.2732	Slightly corrosive
6	9.966944	8.957500	2.72	68.4352	Slightly corrosive
7	9.970278	8.958056	1.94	48.8104	Moderately corrosive
8	9.971667	8.958056	2.31	58.1196	Moderately corrosive
9	9.973333	8.958056	1.02	25.6632	Moderately corrosive
10	9.975000	8.958611	1.19	29.9404	Moderately corrosive
11	9.976667	8.958889	1.21	30.4436	Moderately corrosive
12	9.978056	8.959444	0.89	22.3924	Moderately corrosive
13	9.982222	8.962500	2.84	71.4544	Slightly corrosive
14	9.983889	8.963056	0.65	16.3540	Moderately corrosive
15	9.985556	8.963333	1.25	31.4500	Moderately Corrosive
16	9.987222	8.963889	0.81	20.4551	Moderately corrosive
17	9.988889	8.964167	1.51	37.9916	Moderately Corrosive

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18	9.990278	8.964444	1.26	31.7016	Moderately Corrosive
19	9.991944	8.964444	1.39	34.9724	Moderately Corrosive
20	9.993611	8.965000	1.25	31.4500	Moderately Corrosive
21	9.995000	8.965556	0.99	24.9084	Moderately Corrosive
22	9.996667	8.965556	1.81	45.5396	Moderately Corrosive
23	9.998611	8.964444	1.26	31.7016	Moderately Corrosive
24	10.00028	8.964722	1.48	37.2368	Moderately Corrosive
25	10.00194	8.965000	1.23	30.9468	Moderately Corrosive
26	10.00333	8.964722	1.90	47.8040	Moderately Corrosive
27	9.999722	8.964722	2.38	59.8808	Moderately Corrosive
28	10.00694	8.964722	2.79	70.1964	Slightly Corrosive
29	10.00833	8.965000	0.522	13.13352	Moderately Corrosive
30	10.01000	8.965000	0.91	22.97108	Moderately Corrosive
31	10.01167	8.965278	1.32	33.2112	Moderately Corrosive
32	10.01361	8.965833	1.12	28.1792	Moderately Corrosive
33	10.01500	9.166111	2.06	51.8296	Moderately Corrosive

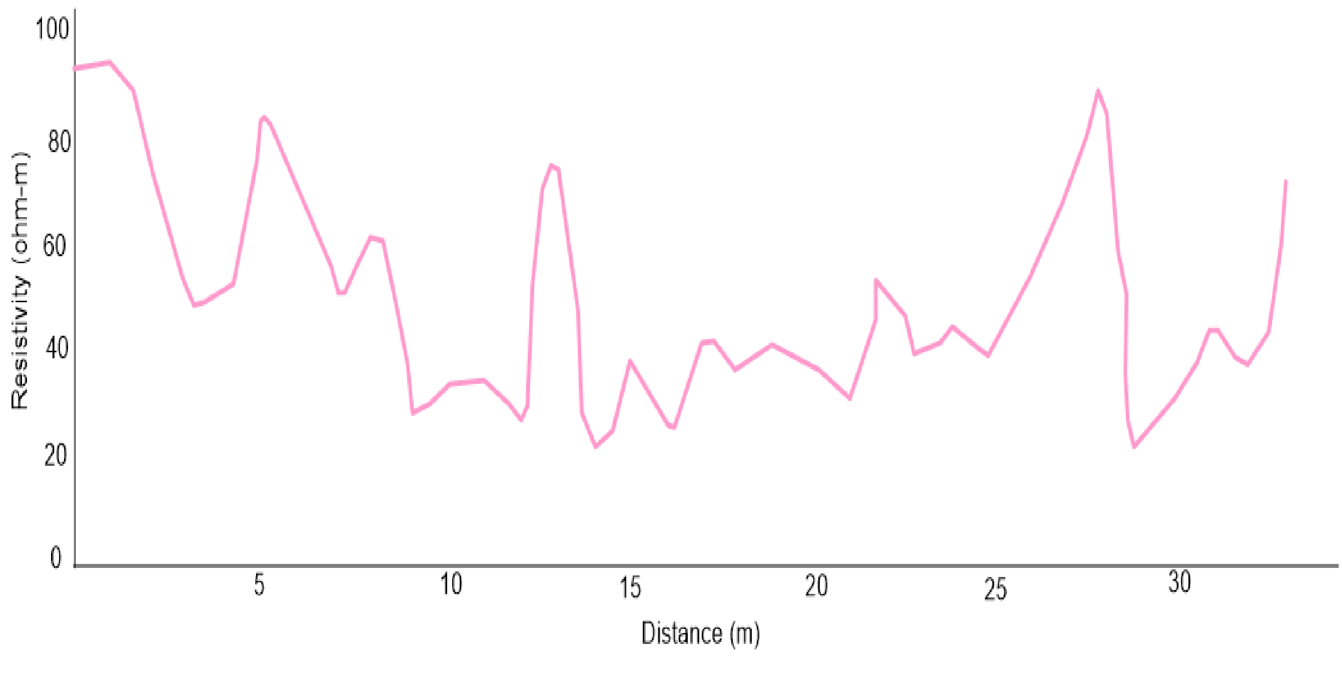

Fig. 4: Graph of Resistivity against Distance showing the Corrosivity of Profile 2 in the study area.

C. Profile Three: Department of Geology

This profile has a total of 32 stations with various resistivity values. From the resistivity values in Table 5 and Fig. 5, the area shows low, intermediate and high resistivity values with the highest value at station 29 (199.0156 Ωm) and the lowest resistivity value of 8.5544 Ωm at station 32. Therefore, comparing this result with Table 1, it can be deduced that the profile is predominantly slightly corrosive representing 66% of the profile while nine (9) of the stations are moderately corrosive which makes up 28 percent of the profile. In this profile, stations 19 and 29 have resistivity values greater than 180 Ωm (Table 5) and hence indicate that the stations are practically non-corrosive. Also, station 32 has a resistivity value less than 100 Ωm (Table 5)

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indicating that the station is very strongly corrosive which could be due to the presence of clay materials around the station. Perhaps, the non-uniformity of soil types within the study area could be responsible for the variation in resistivity values in this station.

Table 5: Summary of Resistivity Values and Corrosivity Rating of Profile 3

P3	NORTHINGS	EASTINGS	RESISTANCE	$2\pi aR$	CORROSIVITY
1	10.08028	8.911944	2.99	75.228	Slightly Corrosive
2	10.08056	8.910833	4.25	106.930	Slightly Corrosive
3	10.08083	8.909722	4.05	101.898	Slightly Corrosive
4	10.08083	8.908333	3.71	93.3436	Slightly Corrosive
5	10.08083	8.907500	6.61	166.308	Slightly Corrosive
6	10.08056	8.907500	5.60	140.896	Slightly Corrosive
7	10.08056	8.905278	3.63	91.331	Slightly Corrosive
8	10.08056	8.903889	3.41	85.796	Slightly Corrosive
9	10.08056	8.903056	1.26	31.702	Moderately Corrosive
10	10.08083	8.901944	2.97	74.725	Slightly Corrosive
11	10.08167	8.900833	2.04	51.326	Moderately Corrosive
12	10.08278	8.900556	2.03	51.075	Moderately Corrosive
13	10.08333	8.899444	1.32	33.211	Moderately Corrosive
14	10.08389	8.898333	1.41	35.476	Moderately Corrosive
15	10.08417	8.897500	1.07	26.921	Moderately Corrosive
16	10.08472	8.896389	2.52	63.403	Slightly Corrosive
17	10.08528	8.895278	1.25	31.450	Moderately Corrosive
18	10.08556	8.894167	3.18	80.009	Slightly Corrosive
19	10.08639	8.893333	7.80	196.248	Practically non-Corrosive
20	10.08694	8.892222	7.11	178.888	Slightly Corrosive
21	10.08722	8.891111	2.24	56.358	Moderately Corrosive
22	10.08778	8.89000	2.45	61.642	Slightly Corrosive
23	10.08833	8.888889	4.56	114.730	Slightly Corrosive
24	10.08917	8.888056	5.12	128.819	Slightly Corrosive
25	10.08944	8.886944	5.44	136.870	Slightly Corrosive
26	10.09000	8.885833	5.56	139.890	Slightly Corrosive
27	10.09083	8.885000	5.43	136.619	Slightly Corrosive
28	10.09111	8.884167	7.30	183.668	Slightly Corrosive
29	10.09167	9.049444	7.91	199.016	Practically non-Corrosive
30	10.09222	9.048333	4.91	123.536	Slightly Corrosive
31	10.09250	9.047500	1.02	25.6632	Moderately Corrosive
32	10.03750	9.046111	0.34	8.554	Very strongly Corrosive

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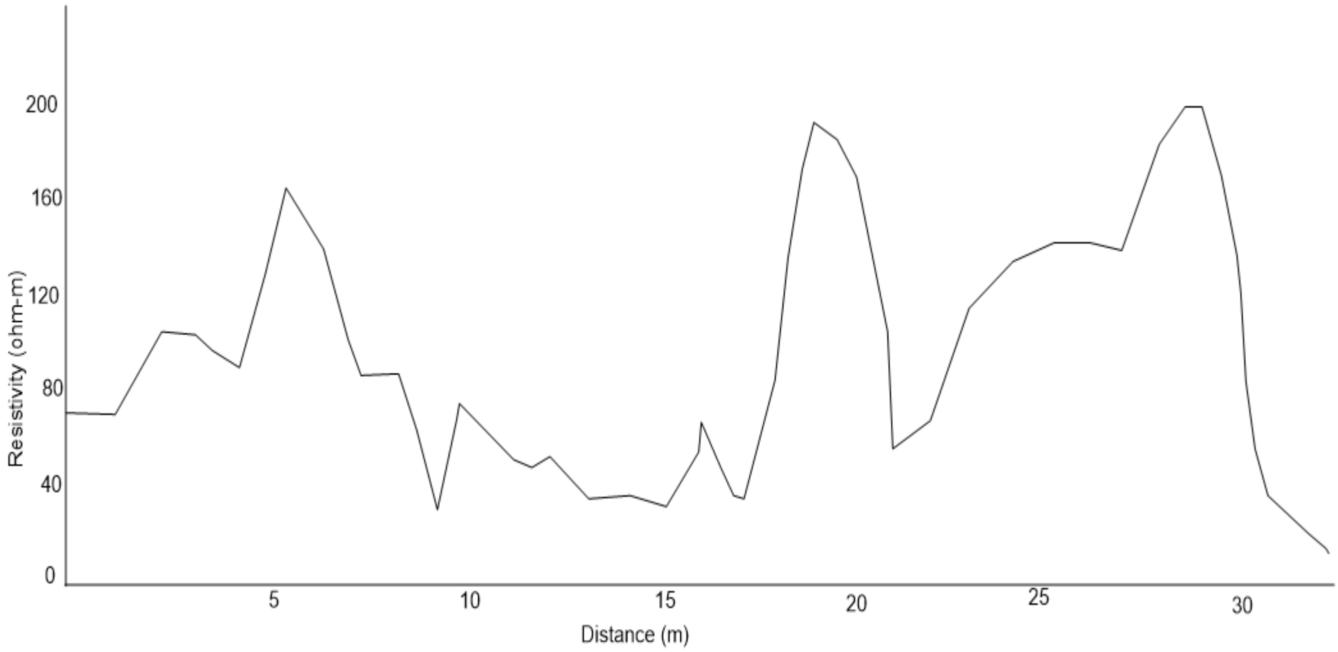

Fig. 5: Graph of Resistivity against Distance showing the Corrosivity of Profile 3 in the study area.

D. Profile Four: Faculty of Arts

This profile has 38 stations showing significant variation in the resistivity values obtained and this ranges from low to intermediate (Table 6 and Fig. 6), with the highest resistivity value of 127.3096 Ωm at station 1 and the lowest resistivity value of 15.3476 Ωm at station 34. In relation to Table 1, the corrosivity of the area ranges from moderately corrosive to slightly corrosive. The resistivity values also indicate that the soil in this profile could be clayey to sandy clay soil (Table 2).

Table 6: Summary of Resistivity Values and Corrosivity Rating of Profile 4

P4	NORTHINGS	EASTINGS	RESISTANCE	$2\pi aR$	CORROSIVITY
1	10.08861	8.891944	5.06	127.3096	Slightly Corrosive
2	10.08972	8.892222	4.45	111.9620	Slightly Corrosive
3	10.09111	8.892778	2.96	74.4736	Slightly Corrosive
4	10.09194	8.893056	2.92	73.4672	Slightly Corrosive
5	10.09333	8.893611	4.42	111.2072	Slightly Corrosive
6	10.09444	8.893889	4.56	114.7296	Slightly Corrosive
7	10.09528	8.894167	4.22	106.1752	Slightly Corrosive
8	10.09667	8.894722	2.55	64.1580	Slightly Corrosive
9	10.0975	8.894722	2.51	63.1516	Slightly Corrosive
10	10.09889	8.895000	2.39	60.1324	Slightly Corrosive
11	10.09972	8.895556	1.74	43.7784	Moderately Corrosive
12	10.10111	8.895278	2.16	54.3456	Moderately Corrosive
13	10.10222	8.895278	3.37	84.7892	Slightly Corrosive
14	10.10417	8.895000	3.49	87.8084	Slightly Corrosive
15	10.10444	8.894444	2.51	63.1516	Slightly Corrosive
16	10.10528	8.894722	1.86	46.7976	Moderately Corrosive
17	10.10667	8.894444	1.10	27.6760	Moderately Corrosive
18	10.1075	8.893889	1.64	41.2624	Moderately Corrosive
19	10.10889	8.895000	2.68	67.4288	Slightly Corrosive
20	10.11000	8.895000	3.42	86.0472	Slightly Corrosive
21	10.11139	8.895278	3.09	77.7444	Slightly Corrosive

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22	10.11222	8.895000	1.57	39.5012	Moderately Corrosive
23	10.11361	8.895278	2.45	61.6420	Slightly Corrosive
24	10.11444	8.895278	2.56	64.4096	Slightly Corrosive
25	10.11583	8.895556	2.22	55.8552	Moderately Corrosive
26	9.966944	8.895278	1.71	43.0236	Moderately Corrosive
27	9.968056	8.895833	3.07	77.2412	Slightly Corrosive
28	9.968889	8.896389	2.66	66.9256	Slightly Corrosive
29	9.970000	8.897500	1.89	47.5524	Moderately Corrosive
30	9.971111	8.896944	2.71	68.1836	Slightly Corrosive
31	9.972500	8.897222	2.10	52.8360	Moderately Corrosive
32	9.973611	8.897222	1.30	32.7080	Moderately Corrosive
33	9.974444	9.097500	1.31	32.9596	Moderately Corrosive
34	9.975833	9.097500	0.61	15.3476	Moderately Corrosive
35	9.976944	9.0980560	0.97	24.4052	Moderately Corrosive
36	9.977778	9.0980560	0.69	17.3604	Moderately Corrosive
37	9.978889	9.0822220	0.60	15.0960	Moderately Corrosive
38	9.980000	9.0991670	0.78	19.6248	Moderately Corrosive

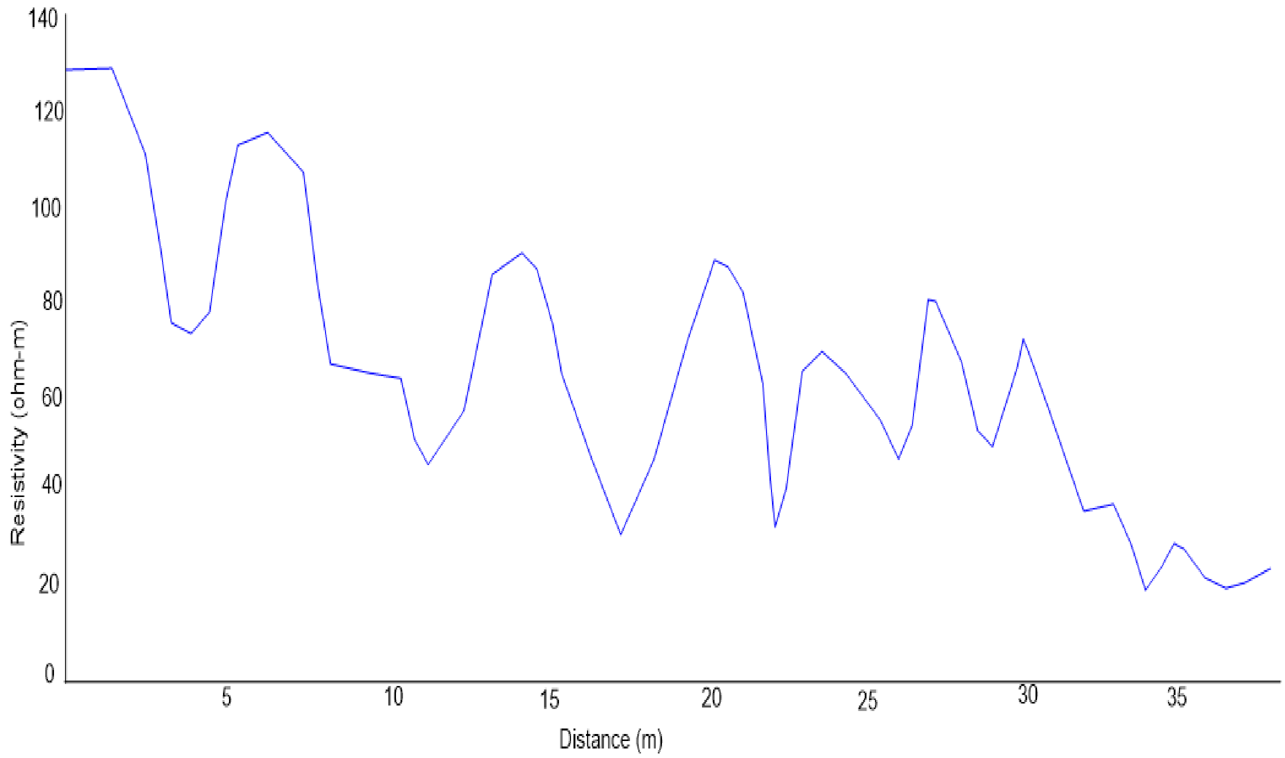

Fig. 6: Graph of Resistivity against Distance showing the Corrosivity of Profile 4 in the study area.

V. GENERAL EVALUATION OF THE CORROSIVITY OF THE STUDY AREA

The resistivity values of the study area on average are generally low with three out of the four profiles showing low resistivity values (Table 7). The profile with the highest average resistivity values was profile one which has an average resistivity value of 369.3847 Ωm. This is because of the presence of sandy clay to clayey sand materials which do not readily retain much water within its pore spaces which act as electrolyte. This however cannot be said of Profiles two, three and four where their average resistivity values ranges from low (42.5951 Ωm) to intermediate (94.7353 Ωm) which may be due to the shallow nature of the chiefly clay materials in the subsurface of the profiles. Figure 7 shows that, the eastern part of the study area has low corrosivity ($\rho \geq 180$ Ωm) whiles the remaining part of the study area indicates high corrosivity ($\rho \leq 180$ Ωm). Over 90% of the

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study area has relatively low topsoil which is characterized by resistivity values with high tendency for corrosivity. However, the section around the eastern part of the study area was designated as practically noncorrosive. Hence, metallic pipes and other critical infrastructures buried around such areas may not be rapidly exposed to corrosion.

Table 7: Statistics of Profile Resistivity Values in the Study Area

Profile	Total VES Points	Resistivity Values (Ωm)		
		Minimum	Maximum	Average
1	21	60.64	707.00	369.3847
2	33	13.13	95.36	42.5951
3	32	8.55	199.02	94.7353
4	38	15.1	127.31	61.1123

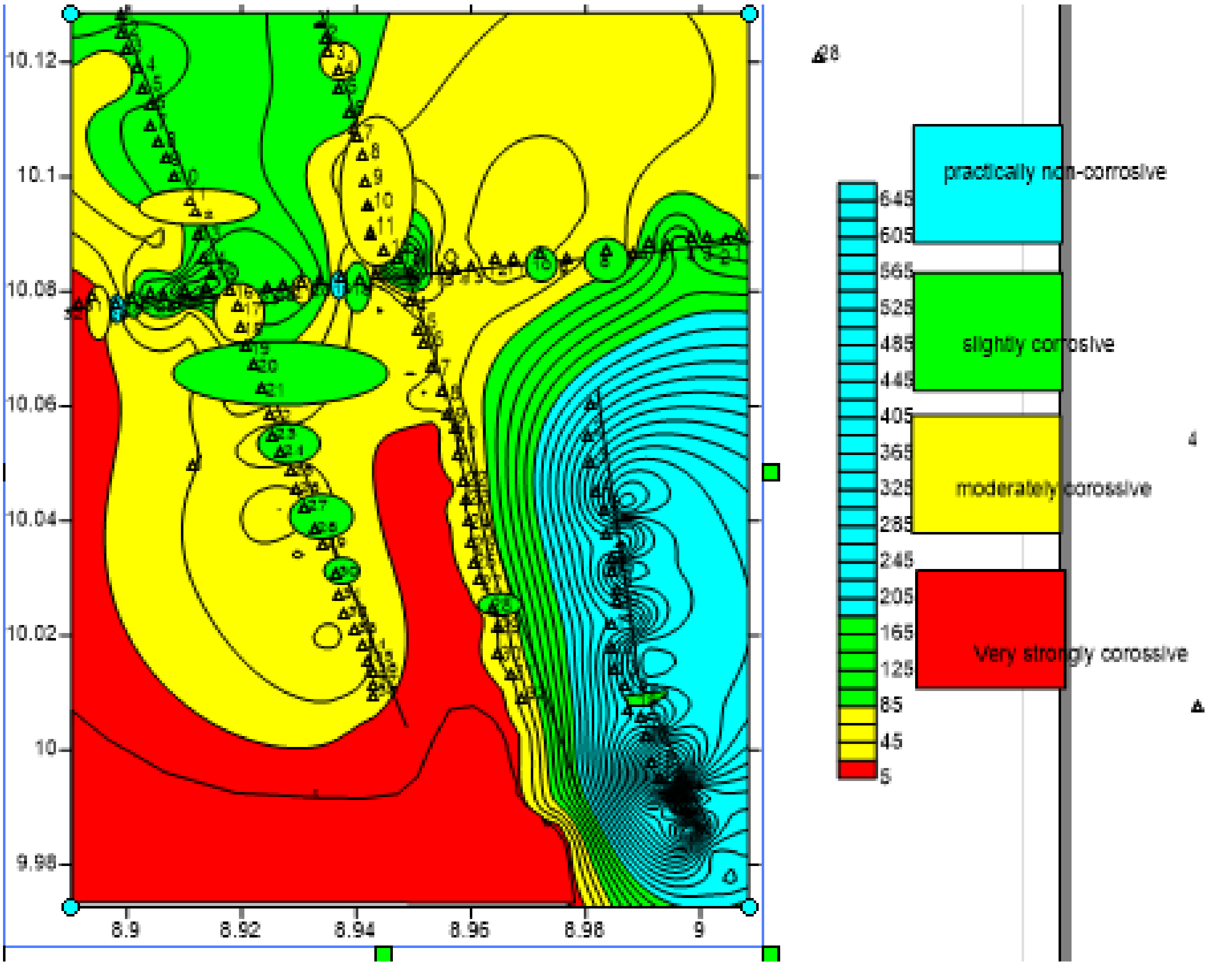

Fig. 7: Corrossivity map of the study area

VI. CONCLUSION

It has been established that, there is a direct relationship between the earth resistance and soil corrosivity of the tested locations in the study area which invariably implies that the lower the soil resistivity, the higher will be the corrosivity value of the soil and vice versa. The locations within the tested sites with high, medium and low resistivity values have been carefully demarcated. It is therefore evident from the study that areas with sandy-clay and clayey-sand have the least corrosive potential while areas with clay materials seem to have the highest corrosivity index.

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It is recommended that materials such as Polyvinyl chloride (PVC) pipes and galvanized metals that are more resistant to corrosion should be used in areas with low resistivity values in order to prevent rapid rate of corrosion. Also, sulphate, chlorite and Soil pH tests of the study area need to be carried out to complement the resistivity study.

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