Science World Journal Vol. 19(No 2) 2024 https://dx.doi.org/10.4314/swj.v19i2.23
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

GEOPHYSICAL INVESTIGATION OF SUBSOIL CORROSIVITY WITHIN UNIVERSITY OF CROSS RIVER STATE, CALABAR, CALABAR SOUTHERN NIGERIA

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ABSTRACT
Assessment of subsoil corrosivity was conducted within the University of Cross River State, Calabar, Calabar Campus, Southern Nigeria. The study employed electrical resistivity methods. The results from vertical electrical sounding revealed that the topsoil of VES_1 and VES_3 was slightly corrosive at depths of 2.20m and 0.70m while that of VES_2 and VES_4 were practically non–corrosive at depths 0.60m and 1.00m. The electrical resistivity tomography across the VES_2 and VES_4 showed a low resistivity at horizontal distances between 5.0m and 10.0m at a depth of 3.75m, indicating very strongly corrosive. Other areas of the profile with resistivity from 19.0 Ώm to 38.0 Ώm at a depth of between 6.38m and 19.8m indicate moderately corrosive and 75.0 Ώm which is slightly corrosive. A resistivity of 148.0Ώm to >580Ώm at the top layer indicates practically non–corrosive at depths 6.38m and 19.4m. Hence, metallic pipes should be buried at depth 3.0m.

Keyword: Vertical electric sounding; electrical resistivity tomography; corrosivity; subsoil; Calabar Campus

INTRODUCTION
One of the critical issues in the construction and building of underground structures and networks is soil corrosion. This is the slow attack of chemical and reduction in quality that leads to the transformation of metal-made materials into salts, oxides or different forms of compounds. When metal-made materials are subjected to corrosion, they will experience low strength, become less ductile and reduce in other mechanical characteristics (Ekine and Emujakporue, 2010).
In towns and cities, distribution of water, gas, crude oil still makes use of metal and alloy pipes. When these pipes break down huge amount of money is spent and there are adverse environmental effects (Okoroafor, 2004). The information about corrosion of the soil will aid in the design and construction of sustainable underground structures. When corrosion information is neglected, the safety of the people will be in danger.
There are so many indices usually employed in assessing corrosivity of soil. These include pH, content of chloride, content of sulphate, electrical resistivity, redox potential, moisture, soil type and soil microbes (Ekine and Emujakporue, 2010; Reza Putra et al., 2018). The pH of soils lies between 5 and 8. Acidic soils have harmful corrosive effects on common construction materials like zinc, cast iron and steel shielding (Fontana, 2005 and Roberge, 2013).
According to Parasnis (1986), corrosivity of soil can be evaluated with the aid of potential methods or electrical methods. These two techniques can be employed to map region of high corrosivity of the soil. The soil corrosivity is the reciprocal of resistivity; this indicates that the lower the resistivity the higher the corrosivity (Andrew et al, 2005). Current flow of ions depends on soil corrosion reaction and an increase in soil resistivity reduces reaction of corrosion (Guma *et al*. 2014). Also soil resistivity in general decreases with an increase in water content and concentration of species of ions (Guma *et al*. 2014).

Several studies have been carried out in different geologic environments to assess soil corrosivity. Evaluation of 137 pipeline failures in six states in the Niger Delta region of Nigeria during 1999-2005 (Achebe et al, 2012); spatial variability of soil resistivity for corrosion risk and intensity in the Niger Delta (Okiongbo et al, 2019); subsoil corrosion at Federal University Oye Ekiti phase11 Campus (Hammed et al, 2017); soil corrosivity in the pre-design of sub-surface water pipe distributary network in Yenagoa, South-South Nigeria (Oki et al, 2016); subsoil corrosivity evaluation in Port Harcourt Metropolis, Nigeria (Ngah and Abam, 2014); assessment of coastal soil corrosivity (Oyedele et al, 2012).
University of Cross River State, Calabar is a learning and residential area. Overtime, construction of underground structures is carried out without knowing the condition of the soil in the area, considering the fact that some materials are prone to corrosion mostly when they are buried. The metal pipes used to connect the water have rusted and are leaking thereby making many buildings not to have water. No geophysical survey has been carried out to assess soil corrosivity in the area.
The objective of this study is to investigate soil corrosivity within University of Cross River State, Calabar, Calabar, Nigeria.

MATERIALS AND METHODS
(a) Hydrogeology and Geology of Study Area
Calabar South experiences peak rainfall in July and September of the year. The area experiences 3000mm of mean yearly rainfall and over 85% of relative humidity (Eni and Efiong, 2011). The three major rivers in the area include Akpayafe, Great Kwa and Calabar emptying into the main Cross River.
The geology is Coastal Plain sands and the lithology comprises alluvium, loose gravel, gravel, clay, lignite and gravel (Short and Stauble, 1967) (Fig.1).

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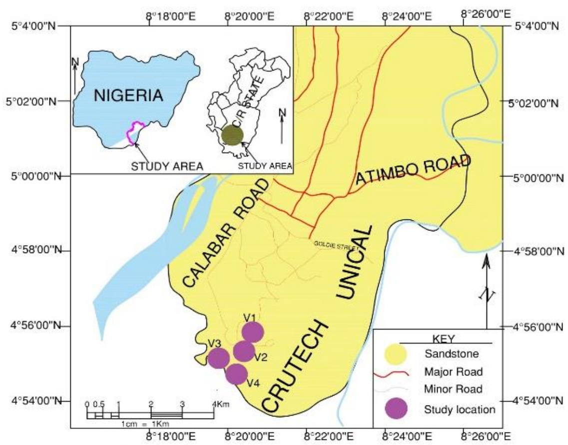

Figure 1. Geologic map of the study area (Drawing Unit, 2023). Department of Geology University of Calabar, Nigeria)

(b) Field procedure

Four (4) vertical electrical soundings (VES) and one (1) electrical resistivity tomography (ERT) of spread length 105m and 300m were conducted. A Resistivity meter Model SSR-MP-ATS IGIS (India) and its supporting items such as cables and reels for current and potential electrodes, measuring tape, hammer, steel electrodes and umbrella were used to acquire the data. The elevations were measured with the aid of GARMIN 12 Global Positioning System (GPS) receiver (Table 1).

Table I: Mid coordinates showing location, latitude, longitude and elevation

VES	Location	Latitude	Longitude	Elevation(m)
1	Behind transformer close to culvert, CRUTECH	N04^{0}55'49.1''	E008^{0}20'00.9''	11.0
2	Behind Hall 3 and Visual Art Department, CRUTEC	N04^{0}55'42.0''	E008^{0}19'59.4''	11.0
3	Infront of ETF1, CRUTECH	N04^{0}55'35.3''	E008^{0}19'42.4''	12.0
4	Infront of New Science Block, CRUTECH	N04^{0}55'30.7''	E008^{0}19'44.8''	10.0

(c) *Vertical electrical sounding (VES)*

Vertical electrical sounding with the aid of Schlumberger array was conducted in the area. The current electrodes were placed outside and the potential electrodes inside and arranged in such a way that AB is equal or greater than 5MN (Hammed et al, 2017). The Resistivity meter measured the resistance of the subsurface soil as the distance between the current and potential electrodes was varied appropriately.

The measured resistance was multiplied by the geometric factor to obtain apparent resistivity. Then this was plotted on the bi-logarithm graph with the aid of Microsoft Excel. Then a WinResit software version 1.0 was employed to invert evaluated apparent resistivity.

Apparent resistivity employed in this study can be expressed as:

$$\rho_a = \pi \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right] R \qquad (1)$$

AB = distance in metres between current electrodes
MN = distance in metres between potential electrodes
R = resistance of the subsurface materials and is given by:

$$R = \frac{\Delta V}{I} \qquad (2)$$

ΔV = change in potential differences measured in volts

I = current in Amperes.

$$\pi = \frac{22}{7}$$

(d) *Electrical resistivity tomography (ERT)*

In this method, a survey was conducted with twenty one (21) electrodes and Wenner array. The separation between the electrodes was varied in steps of 5, 10, 15, 20, 25, 30 and 35m with a spread length of 105m across where VES_2 and VES_4 were conducted. The mechanism of conducting 2D ERT is as presented in (Loke, 2000). The raw data were analysed using RES2DINV version 3.54.44 software.

RESULTS AND DISCUSSION

(a) Vertical electric sounding

The field data resistivity curves and electrical resistivity tomogram in the study are presented (Fig. 2 to Fig.7 and Table 3). Table II and Fig.6 were used to calibrate and identify the lithology in the study area and the results are as shown in Table III.

Fig. 2 and Table 2 indicate that VES_1 is a HAK curve type with five resistivity layers. Layer 1 and layer 2 are moderately corrosive because their resistivity is less than 60 Ωm (Oki *et al*, 2016). The layer 3 is slightly corrosive. Layers 4 and 5 are practically non corrosive because their resistivity is greater than 180 Ωm.

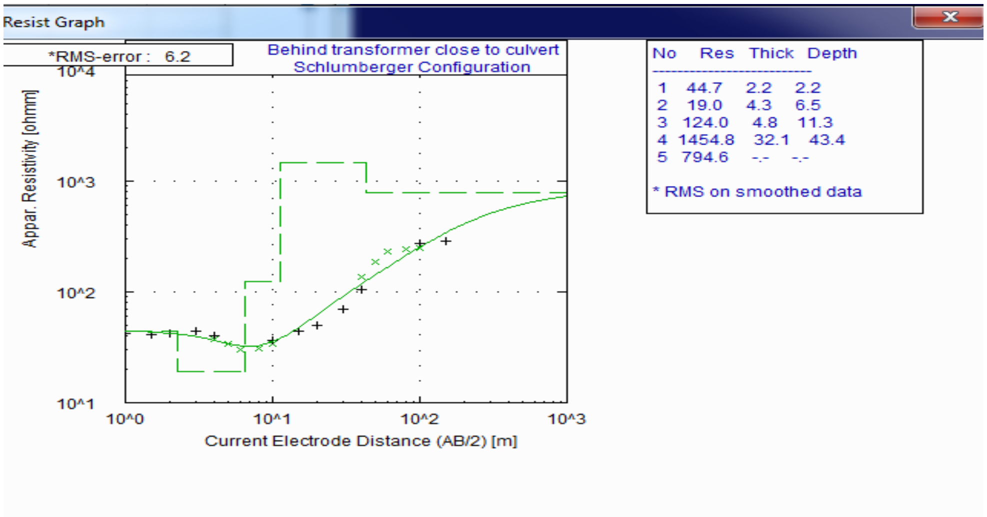

Figure 2. Resistivity curve at Behind the transformer close to the culvert, UNICROSS

Figure 3 shows that VES_2 is a KQ curve. Layers 1, 2, 3 and 4 are practically non-corrosive because their resistivity is greater than 180Ωm.

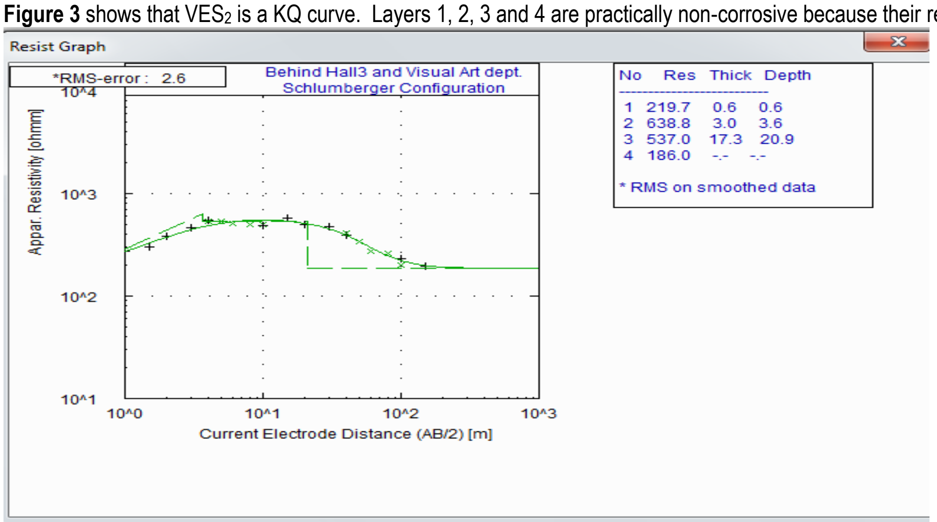

Fig. 3 Resistivity curve behind Hall 3 and Visual Art Department, CRUTECH

Fig.4 and Table 3 reveal that VES_3 is a KHK curve with five resistivity layers. Layer 1 is slightly corrosive with resistivity value of 78.7 Ωm, layer 2 has resistivity value of 722.3 Ωm and is practically non- corrosive, layer 3 has a resistivity value of 146.3Ωm and is slightly corrosive. Layer 4 has a resistivity value of 410.7Ωm and is practically non- corrosive. Layer 5 has a resistivity value of 109.9Ωm and is slightly corrosive.

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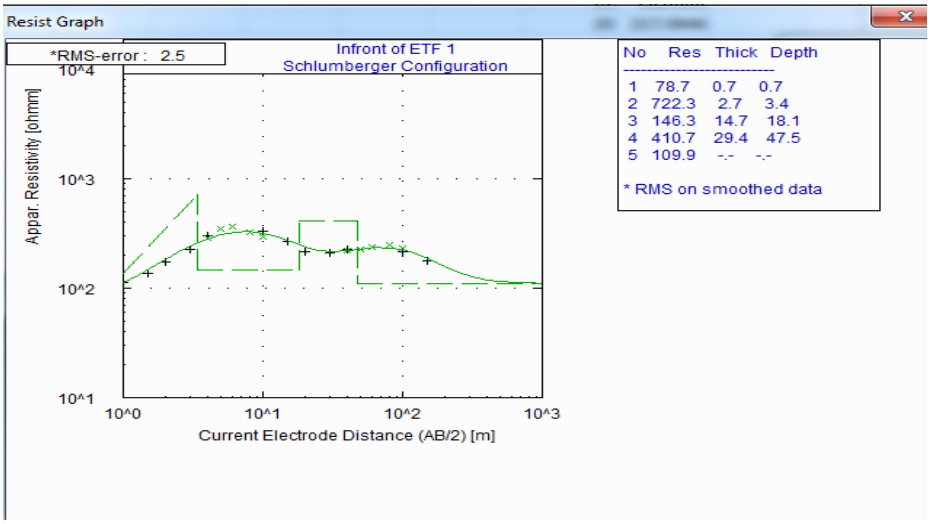

Figure 4 Resistivity curve In front of ETF 1, UNICROSS

Fig 5 and Table 3 indicate that VES$_4$ is a KQ curve type with four resistivity layers. Layer 1 which is the top soil has resistivity value of 295.9Ωm; layer 2 with 962.4Ωm; layer 3 with 258Ωm and layer 4 with 127.5Ωm. Layers 1, 2 and 3 are practically non-corrosive while layer 4 is slightly corrosive.

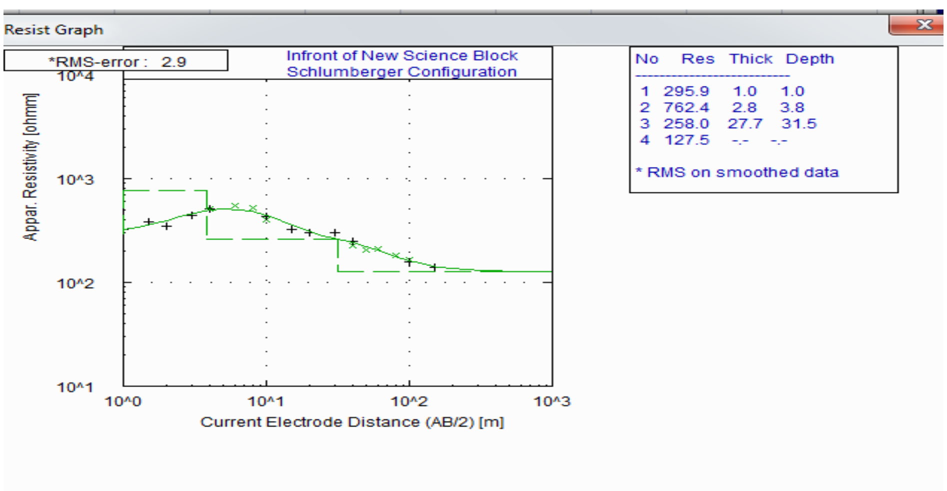

Figure 5 Resistivity curve at Infront of New Science Block, UNICROS

Table 2: Classification of soil resistivity in terms of corrosivity based on (Baekmann and Schwenk, 1975, Agunloye, 1984, Oladapo *et al.* 2004, Oki *et al*, 2016).

Soil Corrosivity	Resistivity (Ohm-m)
Very strongly corrosive (VSC)	<10
Moderately corrosive (MC)	10-60
Slightly corrosive (SC)	60-180
Practically non - corrosive (PNC)	>180

Table 3: Summary of results from resistivity curves

VES	Layer	Resistivity (Ωm)	Thickness (m)	Depth(m)	Lithology	Curve Type	Soil corrosivity
1	1	44.7	2.2	2.2	Top soil	HAK	Moderately corrosive
	2	19.0	4.3	6.5	Clay		Moderately corrosive

	3	124.0	4.8	11.3	Coarse gravelly sand		Slightly corrosive
	4	1454.8	32.1	43.4	Fine-medium sand		Practically non corrosive
	5	794.4	---	---	Fine-medium sand		Practically non corrosive
2	1	219.7	0.6	0.6	Top soil	KQ	Practically noncorrosive
	2	638.8	3.0	3.6	Laterite		Practically noncorrosive
	3	537.0	17.3	20.9	Coarse gravelly sand		Practically non corrosive
	4	186.0	---	---	Fine-medium sand		Practically non corrosive
3	1	78.7	0.7	0.7	Top soil	KHK	Slightly corrosive
	2	722.3	2.7	3.4	Laterite		Practically noncorrosive
	3	146.3	14.7	18.1	Coarse gravelly sand		Slightly corrosive
	4	410.7	29.4	47.5	Fine-medium sand		Practically noncorrosive
	5	109.9	---	---	Fine-medium sand		Slightly corrosive
4	1	295.9	1.0	1.0	Top soil	KQ	Practically noncorrosive
	2	962.4	2.8	3.8	Laterite		Practically noncorrosive
	3	258.0	27.7	31.5	Coarse gravelly sand		Practically noncorrosive
	4	127.5	---	---	Fine-medium sand		Slightly corrosive

In civil engineering work, foundation is usually carried out within the top soil and underground metals and alloys are also embedded in this layer. The thickness of the top soil varied from 0.6m to 2.2m and resistivity value from 44.7Ωm to 295.9 Ωm with average resistivity value of 159.8Ωm. The corrosivity of top soil ranged from practically non - corrosive to moderately corrosive. The top soil layer of VES_2 and VES_4 have relatively high resistivity and therefore practically non – corrosive, while VES_1 is moderately corrosive and VES_3 slightly corrosive (Table 2).
Generally, our results in this study agreed with other studies done in other geologic environments (Hammed et al, 2017 and Gopal, 2010) who found that areas of high resistivity
indicate that the regions are not corrosive while areas with low resistivity are indications that the areas are corrosive.
The soil corrosivity is the reciprocal of resistivity and this indicates that the lower the resistivity the higher the corrosivity (Andrew et al, 2005). Also, current flow of ions depends on soil corrosion reaction and an increase in soil resistivity reduces reaction of corrosion (Guma et al, . 2014).

(b) Electrical resistivity tomography

RES2DINV 3.54.44 was used to analyse ERT data and the inverted resistivity tomogram is presented in (Fig.6).
The Fig.6 indicates that the low resistivity value from 5.0Ώm – 10Ώm is observed at horizontal distance from 0.0m to 10.0m at depth of 6.38m. This implies that the subsoil at this horizontal distance 0.0m – 10.0m at depth 6.38 is strongly corrosive and therefore unsuitable for

underground metals and alloys though they are usually buried at the top layer. At surface points between 10.0m and 100m the top layer has relatively high resistivity 293Ώm to >580Ώm at depths 19.8m and 6.38m. This indicates that the top layer is practically non - corrosive and is good for underground structures.

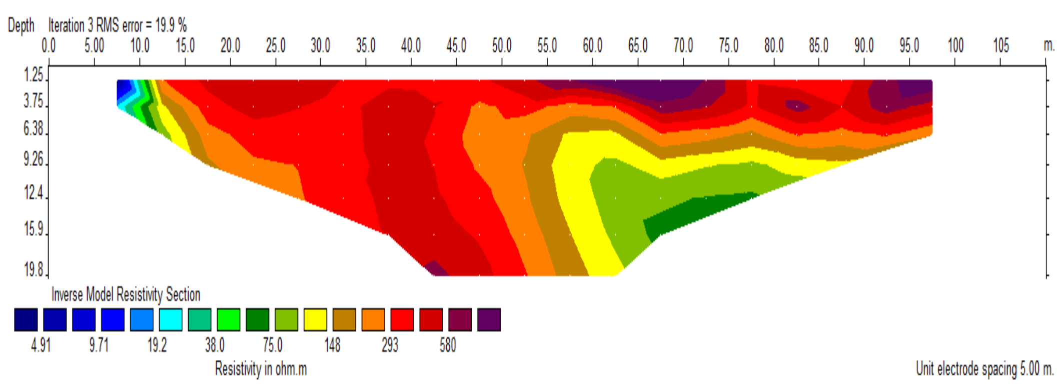

Figure 7 In front of Physics Department, UNICROSS

https://dx.doi.org/10.4314/swj.v19i2.23

Conclusion

This study investigated subsoil corrosivity in University of Cross River State, Calabar, Calabar, Nigeria. The study has successfully characterised the corrosivity of subsoil in the University. The findings of the study revealed that the top soil of VES_1 and VES_3 were slightly corrosive while that of VES_2 and VES_4 were practically non - corrosive. The electrical resistivity tomography across the VES_2 and VES_4 showed a low resistivity at horizontal distances between 5.0m and 10.0m at a depth of 3.75m which indicates very strongly corrosive. Other areas of the profile with resistivity from 19.0 Ώm to 38.0 Ώm at a depth of between 6.38m and 19.8m indicate moderately corrosive and 75.0 Ώm which is slightly corrosive. A resistivity of 148.0Ώm to >580Ώm at the top layer indicates practically non – corrosive at depths 6.38m and 19.4m. Hence, metallic pipes should be buried at depth 3.0m.

Acknowledgements

The author wishes to acknowledge University of Cross River State, Calabar, Nigeria for the permission to carry out this study within the University environment.

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