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EVALUATION OF SOIL CORROSIVITY AT UNGWAN-MAIGERO, CHIKUN LOCAL GOVERNMENT AREA OF KADUNA STATE

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Abstract

Horizontal profiling were carried out within Ungwan-Magerio, Chikun Local Government Area of Kaduna State along eight (8) horizontal profiles using the Wenner array was conducted within the study area, in the NW-SE direction with longitude of 10º 29"250 N and latitude of 07º26"855 E at 582m elevation with profile length of 150 m and electrode spacing of 5 m each. Ohmega resistivity meter was used to acquire these data and interpreted using RES1DINV 1.00.07 and Oasis Montaj software. The longitudinal conductance of the study area ranges from 0.001mhos to 0.8mhos. The corrosivity rating shows 42% practically non-corrosive, 16% moderately corrosive, 37% slightly corrosive and 5% very strongly corrosive. The soil corrosivity was relatively high in profile 6, which represent 5% of the samples showed very strongly corrosive property.

***Keywords*:** Wenner Array, Soil, Corrosivity, Conductance and Profiling.

Introduction

Groundwater is water found within the saturated void underneath the ground, it is contained in the geologic formations called aquifers. Groundwater is recharged by rainfall which moves into the subsurface layers and is available for exploration as rocks of the zone of saturation has sufficient permeability to transmit quality water to wells. The pursuit for good and quality supply of water is on the increase due to increasing population of life (plants and animals). Basher and Main emphasized that groundwater exploration is the most available and convenient natural resources helpful for life's sustenance on earth [1]. Water availability has been vital in all civilization's development. Water scarcity prevents development of settlements in most part of the world [2]. In the absence of reliable water supply the social welfare and economic development are affected in different ways. Soil corrosivity is a geologic hazard affecting buried metals and concrete which are in direct contact with soil or bedrock [3]. The first layer resistivity at each location was used to determine the soil corrosivity in the study area and it has been compared with the classification shown in Table 1. The Dar-Zarrouk parameters (second order geoelectric parameters) are estimated from the first order parameter (resistivity and thickness) of the geoelectric layers which are the aquifer protective capacity classification. [4]. was the first to propose the Dar-Zarrouk parameter concept, the postulation holds that the thickness and resistivity of lithologic layers are known; the transverse resistance (R) and longitudinal conductance (S) are easily calculated. Hence the correlation resistivity values are determined. Secondary geoelectric parameters (longitudinal conductance (S), transverse unit resistance (T), and coefficient of Anisotropy (λ) are important in describing geoelectric section with several layers [5].

Table 1. Soil Resistivities versus Corrosivity [3].

S/N	Soil resistivity (Ohm-m)	Soil corrosivity
1.	10	very strongly corrosive(VSC)
2.	10-60	moderately corrosive(MC)
3.	60-180	Slightly corrosive (SC)
4.	> 180	Practically Non-corrosive (PNC)

[6] investigated aquifer protective capacity, soil corrosivity, and Dar-Zarrouk characteristics in the Kaura area of Kaduna state, Nigeria. The study found that 35% of the aquifers had good protective capacity, while the remaining 65% have moderate protective capacity. At one location, the upper layer was determined to be moderately corrosive; four others were found to be slightly corrosive, and the rest were found to be practically non-corrosive. The reflection coefficients and

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resistivity contrast indicate high groundwater potentials; the coefficient of anisotropy had a high average value of 1.57 in the western section and a low average value of 0.70 in the central and eastern part. A high coefficient of anisotropy indicates a high water-holding capacity and, as a result, a high porosity.

The fast growing population within Chikun L.G.A of Kaduna State, more wastes are being generated which are potential contaminants to groundwater. The siting of dumpsites and latrines are done without proper hydrogeological consideration of the area and as such endangers groundwater. Hazardous chemicals such as herbicides, pesticides, solvents are commonly used within the study area. These chemicals reach the groundwater overtime through leachates contaminating it. Hence, the soil corrosivity evaluation within the study area has become imperative.

Because of the presence of the Kaduna State Water Corporation (KADSWAC) situated within the study area with buried pipes for distribution of water to residents, there is the possibility of corrosion adding to contamination of ground water which is already threatened by existing dumpsites within the area. The geophysical methodology adopted in this work provides electrical properties of the subsurface that help determine the degree to which the groundwater in this area is contaminated. Hence informed decision on siting and management of groundwater resources for development purposes can be reached. Thus, this research work aims to evaluate soil corrosivity of the study area.

Geology of the Study Area

This study was carried out within the Nigeria Crystalline Basement Complex, the area lies between the Guinea savannah belts, with two tropical climates with two distinct seasons: the rainy season which begins around April and ends in October and the dry season running from November through March. The average annual rainfall in Kaduna (which consist of the study of study) is 300 mm as shown in Figure 1. Rainfall generally reaches its peaks in august and its mean temperature of about 29 $^{\circ}$C in March/April. The major River Kaduna controls the course of most of the rivers [7]. The sites are accessible by foot, bicycle and motorcycles.

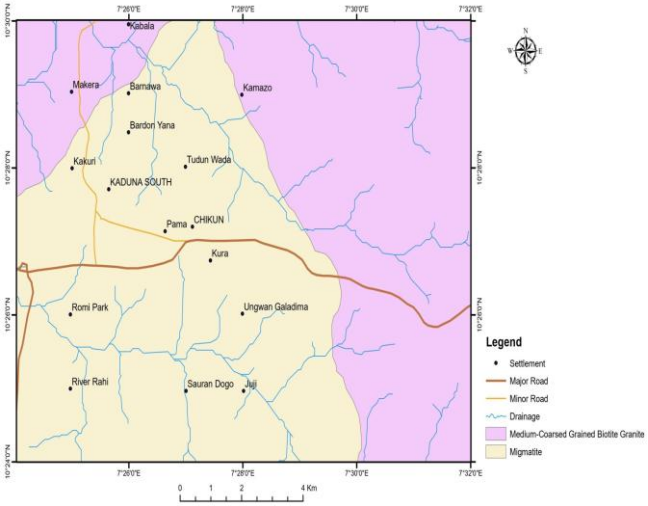


Figure 1.0 Geological map of Chikun (After Nigeria Geological Survey Agency 2021)

Materials and Method

Materials

The following are the materials used in the research: Ohmega resistivity meter; Measuring tape; Current wires; Electrodes; Res 1d version 1.00.07 beta modeling software; Hammer; Connecting wires and Global positioning system (GPS).

Methods

Vertical Electrical Sounding is a geophysical surveying technique used in subsurface layered electrical prospecting. It calculates the vertical variation in resistivity as a function of depth [8]. This feat is predicated on the assumption that the surface is homogeneous and isotropic [9].

The current I and potential V in a metal conductor at constant temperature are connected as follows according to Ohm's law:

$$V = IR \quad (1)$$

Where R is the constant of proportionality known as resistance, measured in ohm. The resistance R, of a conductor is related to its length r and cross sectional area A, by

$$R = \frac{\rho r}{A} \quad (2)$$

Where ρ is the resistivity, and it is a property of the material considered.
From equation (3.1) and (3.2),

$$V = \frac{I\rho r}{A} \quad (3)$$

During the field procedure, the following precautions were taken.

i. It was ensured that the electrodes penetrated well into the ground in order to have good contact by hammering it deep into the ground.
ii. It was ensured the connection was carefully made.
iii. Caution was taken while laying the wires for effective current flow.
iv. The resistivity meter was turned off after each successive reading and ON when taking the next reading.

Horizontal Profiling

Surveys of lateral variations can be conducted at specific spots, grid points, or along defined lines of traverse, a technique known as Wenner array. Horizontal Profiling entails moving the array over a traverse line, while horizontal variations can alternatively be explored using individual measurements taken at grid points [10]. Horizontal profiling involves choosing a constant electrode spacing (based on the electrical sounding results) and moving the entire electrode array along a profile after each reading to estimate the horizontal variation of resistivity, as shown in Figure 1.1.

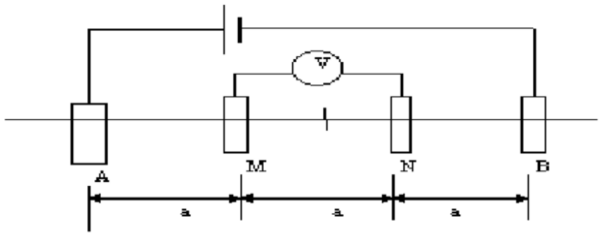


Figure: 1.1 Wenner array

$$V_1 = \frac{A_1}{r_1} \quad (4)$$

Where

$$A_1 = \frac{I\rho}{2\pi r_1} \quad (5)$$

Similarly, the potential due to C_2 at P_2 is

$$V_2 = \frac{A_2}{r_2} \quad (6)$$

Where

$$A_2 = -\frac{I\rho}{2\pi r_2} \quad (7)$$

Since the potential of the two electrodes are equal and opposite in direction, we have

$$V_1 + V_2 = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad (8)$$

By introducing a second potential electrode at P2, we can measure a difference in potentials between P1 and P2 to be

$$\Delta V = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right) \quad (9)$$

Taking the spacing to be a, such that $r_1 = r_4 = a;$ and $r_2 = r_3 = a$ substituting these values in equation 3.2, we have

$$\Delta V = \frac{I\rho}{2\pi a} \quad (10)$$

Therefore;

$$\rho(wenner) = \frac{\Delta V}{I} 2\pi a \quad (11)$$

Or

$$\rho_a(wenner) = 2\pi a R \quad (12)$$

Where $R = \frac{\Delta V}{I}$ (from ohms law)

$\rho_a(wenner)$ Is the apparent resistivity due to wenner array.

Choice of Electrode Configuration

The type of electrode array to be used in any geophysical work depends largely on the interest, that is, whether the interest is finding lateral variation in resistivity or finding the variation of resistivity with depth [11]. Though there are different arrays that can be used to carry out electrical resistivity survey for the subsurface ground condition, but Wenner array is used in this work. Because of its speed, simplicity, and practicality, the Wenner probe technique is the most widely utilized approach. It can be used to measure the resistivity of concrete from the surface in seconds, without the need for invasive procedures like coring.

Data acquisition for horizontal Profiling

The current electrodes A and B represent the current electrodes through which the current was transferred into the ground through the anode in the Wenner array that was used. M and N are the potential electrodes across which the current-induced potential difference was measured. All four electrodes A, B, M, and N are positioned on a straight line at equal distance from each other in this setup. A total of eight (8) horizontal profiling data were collected along areas containing underground pipes, with an azimuth of NW-SE and a maximum profile length of 150 meters for each profile with a 5meter interval. Equation (K=2πa) was used to calculate the geometrical factor values. On a log-log graph sheet, the acquired resistivity (ρ) values were plotted against the half current electrode separation (AB/2). On the graph, resistivity (ρ) is on the ordinate, whereas electrode spacing (AB/2) is on the abscissa.

Results and Discussion

Profile 1

The horizontal profile of Figure 1.2 was taken along water-intake at ungwan-magerio, suspected areas with buried pipes in the NW-SE direction with longitude of $10^0 29''250N$ and latitude of $07^0 26''855E$ and elevation of 582m.The profile length is 150m with electrode seperation (α) of 5m for each of the eight (8) horizontal profile, the result was interpreted based on the soil resistivity/ soil corrosivity rating shown in Table 1, Profile 1 reveals slightly to practically non-corrosive (SC) and (PNC) ranging from 70 -190 ohm-m (SC) indicated red, and >190 ohm-m (PNC) indicated green.

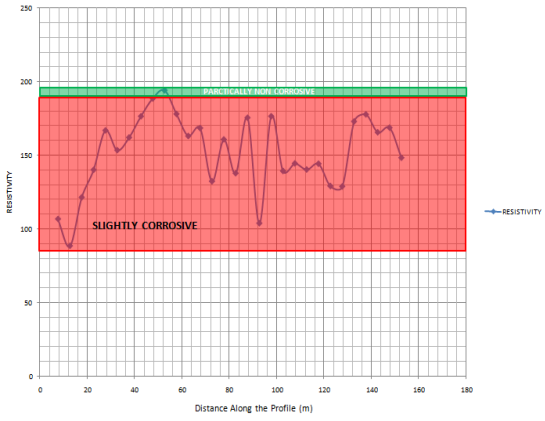


Figure 1.2 horizontal profile of the study area across profile 1.

Profile 2

Figure 1.3 of the horizontal profile reveals 50-190 ohm-m slightly corrosive (SC) and practically non-corrosive >180 ohm-m (PNC) with colour indication of red and green.

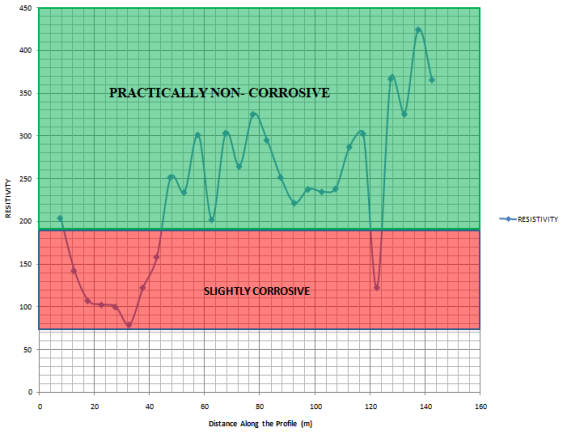


Figure 1.3 horizontal profile of the study area across profile 2

Profile 3

Drawing from the soil resistivity/ soil corrosivity rating shown in Table 1, profile 3 of the horizontal profile (figure 1.4) revealed moderately corrosive (MC) with range of 30 -60 ohm-m and its indicated with blue colour and >180 ohm-m as practically non-corrosive (PNC).

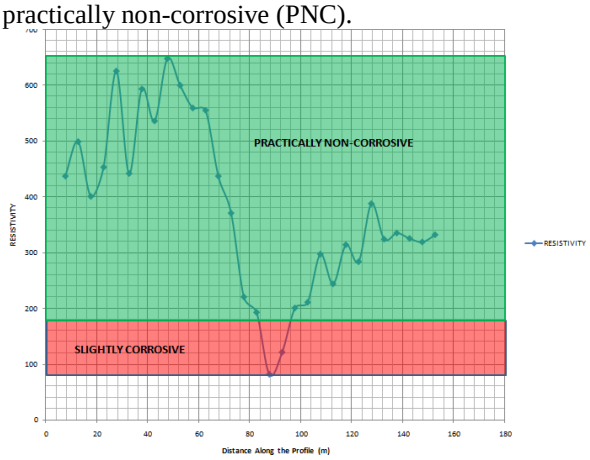


Figure 1.4 horizontal profile across the study area of profile 3

Profile 4.

The horizontal profile of figure 1.5 in the NW-SE direction with longitude of $10^0$29’’165N and latitude of $07^0$27’’114E and elevation of 592m. AB of 145m with interval of 5meters, the result was interpreted according to the soil resistivity/ soil corrosivity rating shown in Table 1, Profile 4 reveals slightly corrossive (SC) ranging from 60-190 ohm-m and is indicated red, and >180 ohm-m as practically non-corrossive (PNC) indicated green.

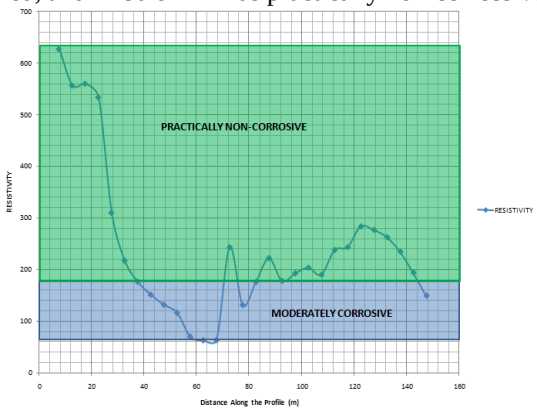
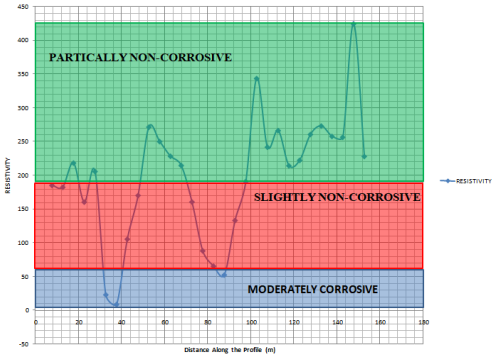


Figure 1.5 horizontal profile across the study area of profile 4.

Profile 5.

Figure 1.6 with longitude of $10^{0}29'144N$ and latitude of $07^{0}27'122E$ with elevation of 601m. profile 5 reveals three (3) of the soil resistivity/ soil corrosivity rating of Table 1. profile 5 having moderately corrosive (MC) ranging from 10-60 ohm-m colour indicated as blue, slightly corrosive(SC) 60-190 ohm-m indicated as red and > 180 practically non-corrosive (PNC) indicted as green.



Fiqure 1.6 horizontal proile across the study area of profile 5.

Profile 6

Based on the soil resistivity/ soil corrosivity rating of Table 1. having four (4) classification ratings of which all four (4) where identified in profile 6 with resistivities less than 10 ohm-m representing very strongly corrosive (VSC) region coloured yellow, 10-60 ohm-m moderately corrosive (MC) indicated as blue, 60-190 ohm-m slightly corrosive (SC) indicated as red and >180 ohmm as prctically non-corrosive (PNC) indicated as green.

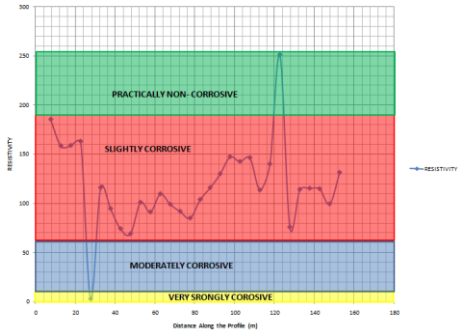


Figure 1.7 horizontal profile of the study area across profile 6.

Profile 7

Figure 1.8 is the horizontal profile for profile 7 which shows 60-190 ohm-m as slightly corrosive (SC) it's indicated as red and >180 ohm-m as practically non-corrosive (PNC) indicated as green, and it's according to the classification of Table 1.

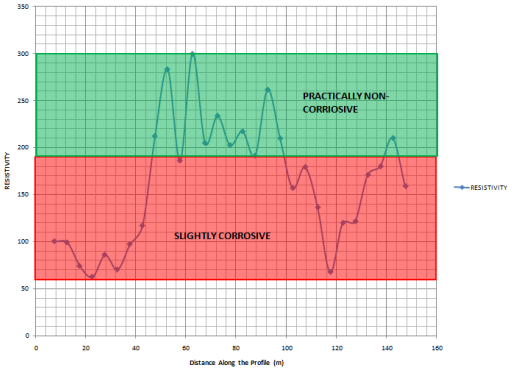


Figure 1.8 horizontal profiles across the study area of profile 7.

Profile 8

Figure 1.9 of the horizontal profile of the study area across profile 8 revealed slightly corrosive 60-180 ohm-m indicated as red and > 180 ohm-m as practically non-corrosive indicated as green.

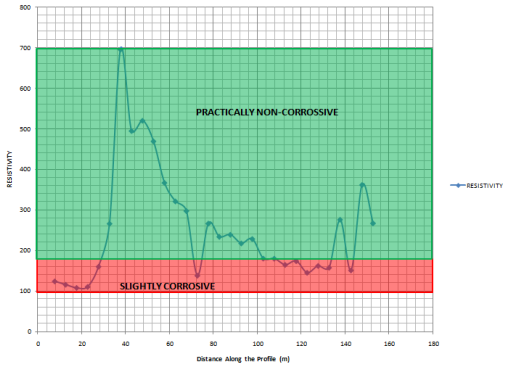


Figure 1.9 horizontal Profile Across the study area of profile 8.

The soil corrosivity rating of the research area has been statistical summarised in figure 1.10 showing that 42% of the profiles exibited practically non-corrosive character, 37% is slightly corrosive, 16% moderately corrosive and 5% very strongly corrosive.

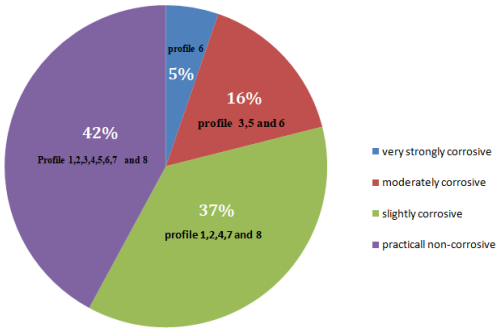


Figure 1.10 Soil Corrosivity Rating

Conclusion

Eight (8) horizontal profiling data were carried out in Northwest - Southeast (NW-SE) azimuth using Wenner array. All of the horizontal profiling taken, the 8 profiles, profile 1,2,4,7 and 8 reveals slightly corrosive (SC) and practically non – corrosive(PNC) ranging from 60-180, profile 3 reveals moderately corrosive (MC) and practically non-corrosive (PNC), profile 5 reveals moderately corrosive (MC) slightly corrosive (SC) and practically non-corrosive (PNC) and profile 6 reveals very strongly corrosive (VSC), moderately corrosive (MC), slightly corrosive (SC) and practically non- corrosive based on the thickness and resistivities of the overburden layers.

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