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The Use Of A Digital Resistivity Tool For Investigating Variations In Depths To Aquifer At Amachree Area In Buguma, Rivers State.

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Abstract: This study investigates the subsurface hydrogeological conditions of Buguma in the Niger Delta, with a focus on identifying zones of iron-rich water and saltwater intrusion that threaten groundwater quality. Electrical Resistivity Tomography (ERT) was applied to characterize the subsurface and delineate conductive zones that reflect different contamination sources. The resistivity tomogram reveals a shallow conductive layer interpreted as an iron-water formation zone, likely resulting from the mobilization of ferruginous minerals under changing redox conditions. This zone shows a progressive downward extension, indicating infiltration into deeper aquifer units. At greater depths, a distinct low-resistivity zone was identified, consistent with saltwater intrusion extending laterally and vertically through the subsurface. The continuous conductive signature from shallow to deep levels suggests a vulnerable aquifer system with direct hydraulic connectivity, allowing contaminant mixing and reduced freshwater quality. The geological framework, dominated by unconsolidated sands and interbedded clays of the Benin Formation, enhances permeability and further supports the downward and lateral migration of contaminants. The results highlight a dual contamination scenario: ferruginous enrichment at shallow depths and saline intrusion at greater depths. This poses a serious threat to sustainable groundwater use in Buguma. Immediate mitigation measures such as controlled abstraction, monitoring, and aquifer protection are recommended to preserve groundwater resources.

Keywords: Buguma, ERT, iron water, saltwater intrusion, Benin Formation, groundwater vulnerability, Niger Delta.

Introduction

Groundwater remains a critical source of potable water in many coastal communities of the Niger Delta, including Buguma in Rivers State. In these areas, dependence on groundwater has increased due to the contamination of surface water from both natural and anthropogenic activities. However, the proximity of coastal aquifers to tidal creeks and estuarine systems makes them highly vulnerable to both iron water contamination and saltwater intrusion (Nwankwoala & Udom, 2011; Udom et al., 2022). These processes lead to a deterioration of groundwater quality, posing risks to public health, infrastructure, and water security. The increasing demand for potable water in the Riverine areas of Niger Delta has called for a scientific approach to the existing insufficient water supply in the region. The attempt to augment surface water supply and rain harvesting, which is of narrow opportunity in the Niger Delta with groundwater has called for a critical groundwater research.

Iron contamination commonly originates from the dissolution of ferruginous sediments or redox reactions in the subsurface, increasing electrical conductivity and changing water chemistry (Appelo & Postma, 2005). Saltwater intrusion, on the other hand, occurs when saline water from marine or estuarine environments migrates inland into freshwater aquifers due to over-abstraction, sea-level rise, or natural hydraulic connectivity (Barlow & Reichard, 2010; Werner et al., 2013). Both contaminants exhibit low resistivity, making geophysical methods particularly Electrical Resistivity Tomography (ERT) effective for identifying and delineating their distribution (Loke et al., 2013; Chambers et al., 2014).

This study focuses on the hydrogeophysical assessment of the subsurface in Buguma using ERT to characterize zones of ferruginous water formation at shallow depths and saltwater intrusion at greater depths. The findings aim to support sustainable groundwater development and guide remedial strategies to protect aquifer integrity in the area. Thus, it is imperative to take a detail look on the water resources in Prince Kariboye George Amachree's Area, Buguma, Rivers State, because of its expanding population, especially in this coastal region. However, proper management, development, and use of fresh water in coastal areas are necessary to prevent saltwater contamination of existing water supplies. Sound management decisions can be made best when based on available information; therefore, it is desirable to gather as much data as is economically reasonable to support these decisions. The essence of employing the use of electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface and with the view of understanding certain points along the earth surface in which borehole drilling can be done. From these measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the heavy metals, fluid content, porosity and degree of water saturation within the subsurface layers. Electrical resistivity surveys have been used for many decades in hydrogeological (involving borehole drilling activities), mining and geotechnical investigations. More recently, it has been used for environmental surveys.

Extensive exploitation of coastal aquifers that are hydraulically connected to the sea usually results in a reduction in groundwater quality due to seawater intrusion. However, continued groundwater withdrawals, compounded by a decrease in groundwater recharge, can trigger the seawater–freshwater interface to move inland resulting in additional salinization of the coastal aquifer. In this case, coastal aquifers are threatened by an increase in seawater intrusion with sea level rise.

One of the methods of monitoring depths to iron water presence within the subsurface rock layers and saltwater movement in coastal areas is the use of electrical resistivity. This method allows monitoring of a large area at a comparatively small cost. In addition, surface resistivity measurements can be used to give supplemental water quality control in areas between observation wells. The purpose of this study is to investigate using electrical resistivity tools (ADMT: Digital Resistivity Terrameter and Pool Finder Plus) to aid in defining depths to fresh water Aquifers, iron water presence and fresh water/saltwater interface at the subsurface layers in Prince Kariboye George Amachree's Area, Buguma, Rivers State.

Geologic Setting and Hydrogeology of the Area

Buguma is located within the central part of the Niger Delta sedimentary basin, a geologic province characterized by thick sequences of unconsolidated to semi-consolidated sands, gravels, and clay interbeds belonging predominantly to the Benin Formation. This formation is Pliocene to Recent in age and is highly porous and permeable, making it a major regional aquifer (Short & Stauble, 1967).

Structurally, the Niger Delta is a wave- and tide-dominated prograding delta with subtle growth faults, gentle folding, and active subsidence. These features, combined with the low elevation and shallow water table, make the aquifer system especially sensitive to contamination from surface and coastal processes (Reyment, 1965; Short & Stauble, 1967). The geology, therefore, not only supports abundant groundwater resources but also makes them vulnerable to saline encroachment and ferruginous contamination. The area is within the Niger Delta of Southern Nigeria and it shows an arcuate shape, wave and tide dominated prograding Deltaic system. The sediments range from Eocene to Quaternary. The Niger Delta is basically made up of three Formation such as Benin, Agbada and Akata respectively (Figure 1).

Aquifers of the Benin Formation (where this work was done) bears the ground water needs of the region, the poorly sorted coastal sands become increasingly sandy and unconsolidated towards the surface. These parameter increases the porosity and permeability and thus, the increase in storage coefficient of the aquifer. Recharge through the surrounding water bodies and extensive rainfall percolating down with a fairly, thick vegetation run-off is negligible, this has resulted in a prolific hydrologic unit within the area.

It is typified by uniformly high temperature throughout the year, intense rainfall which occurs almost every month of the year, seasonally variable and energetic in down pour with increasing distance from the ocean (Mmom and Fred-Nwangwu, 2013). This often graduates to thunderstorm at its onset and cessation with variation in duration and amount between 4,700mm and 4,500mm in July – September, especially in popular rainfall stations like Opobo, Okrika and Bonny that are in the same geographical location

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with Buguma City (Fashiola et al, 2013). The riverine area encompassing Buguma in Asari-Toru Local Government Area of Rivers State is divided into three main hydro-vegetation zones. The beach ridge is extensively vegetated by fresh water swamp trees, palm and shrubs on the sandy ridges and mangroves in the intervening valleys, creeks or tidal flats. The salt-water (mangrove) swamp zone is the tidal flat vegetated by the red salt-rooted mangrove (Rhizophoraracemosa) and two other species including the nypa palm that grows extensively under the influence of brackish water system and marine regimes. The fringe areas of raised alluvial coastal plain terrace within the swamps are vegetated by tall luxuriant forest tree species and oil palm.

Buguma town is an administrative town as it is the headquarters of Asari-Toru Local Government Area. It is also a traditional headquarters of the Kalabari ethnic nationality. Buguma can be accessed by road and water from Port Harcourt and all other towns and villages surrounding. The town has a general hospital and as well as three primary school and secondary schools and also a magistrate court. The main economic activities in the area are transportation, fishing, trading and other local craft activities. Tourists are attracted to the place because of it natural beaches and also the traditional festivals that go on every quarter of the year.

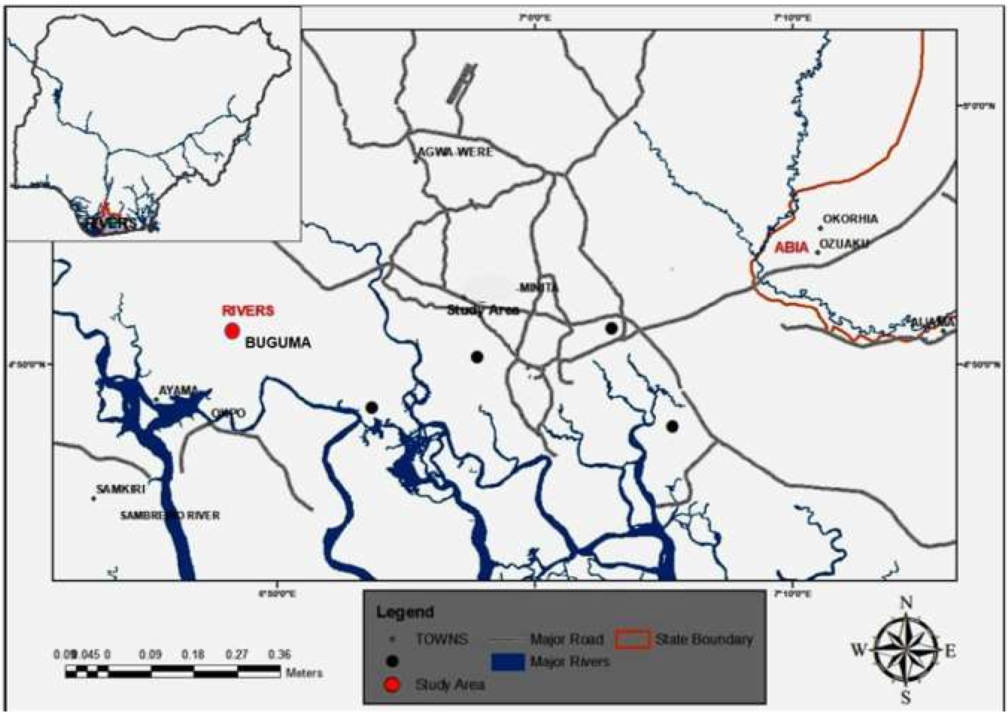

Figure 1: Geologic map of the study area.

Methodology

The work involves the use of electrical resistivity method (Figure 2 and Figure 3) in exploring for Aquifer depths to freshwater Formation for borehole drilling and to evaluate areas within the subsurface layers where saltwater intrusions into freshwater zones occur.

The instrument is connected to the APP through the built-in Bluetooth, so you can use the APP to realize all the operations of the instrument such as measurement signal input, data checking and processing. Using wireless sensor probe, you can complete all the measurements just by walking and stopping. No need long cable, saving time and manpower.

ADMT series products are a new generation intelligent prospecting instruments designed by AIDU and Guilin Technology Hydrogeological Investigation Institute. Based on more than 4 decades R&D experiences, we use mobile phone or table PC to run the complicated data calculation to realize the quickly calculation inversion and rapid graph drawing. Then we can quickly draw

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2D/3D profile maps, contour maps and curve diagrams by an APP. This is a leap in technology because it makes the complicated geophysical survey becomes easier and simpler. With the APP you could use many intelligent functions such as field measurement control, instantly data process, data cloud backup, online expert analysis and Bluetooth data transaction etc.

Main Features

The main features include:

1. Instant Mapping: Directly drawing the 2D/3D map by the APP after data collection
2. Simple Operation: Walking and stopping to complete the measurement, so easy.
3. Efficiency: Unique wireless prospecting tech, one person can complete all work, saving time and manpower.
4. Precision: Strong anti-interference ability, field source correction and patent tech to process data.

Many innovative designs make the instruments become more intelligent, efficient and accurate to obtain dozens of invention patents.

Figure 2: A digital Terrameter for Groundwater Exploration.

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Figure 3**:** A Pool Finder Plus for Groundwater Exploration.

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Results and Discussion

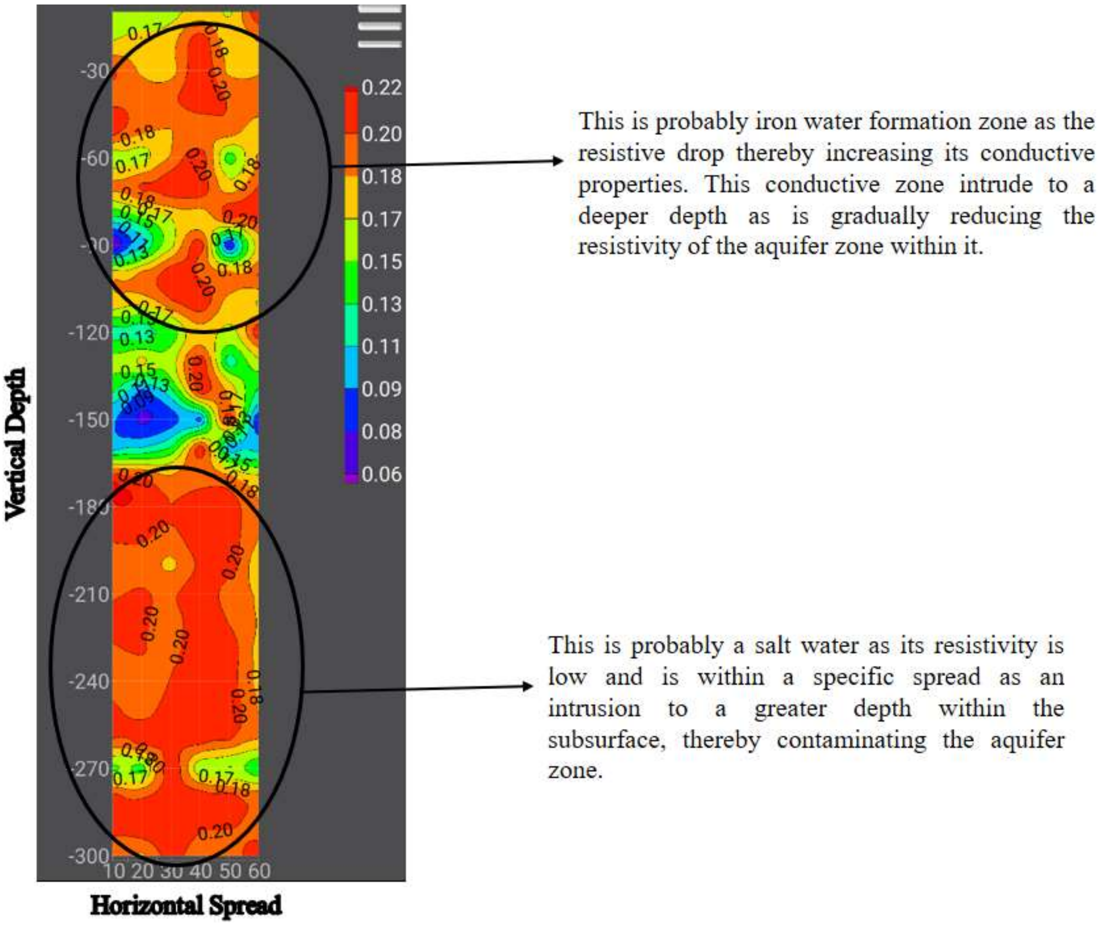

Figure 4**:** The ERT subsurface image of Buguma

The ERT interpretation indicates a shallow zone where resistivity drops markedly, implying increased electrical conductivity consistent with an iron-rich groundwater (ferruginous) formation. In such a setting, dissolution of iron-bearing minerals or mobilization of iron due to changing redox conditions raises ionic strength and so lowers resistivity; this matches the tomogram signature of a highly conductive shallow horizon. From that shallow horizon the conductive signature continues downward gradually reducing resistivity through the overlying aquifer which is best interpreted as the ferruginous (iron) fluid plume intruding into deeper parts of the aquifer and progressively increasing the bulk conductivity of those units.

Beneath and adjacent to this iron-affected interval, a laterally distinct, low-resistivity body occurs within a defined spread and at greater depth. The magnitude and continuity of the low resistivity at depth are typical of saline (salt) water intrusion into the freshwater system: saline water has high ion concentration and therefore very low resistivity relative to fresh pore waters or dry sediments. The geometry of this anomaly its lateral extent and vertical continuity with depth indicates an advancing saltwater front that is contaminating deeper aquifer horizons. Because both the shallow ferruginous zone and the deeper saline zone are electrically conductive and are observed to be continuous with depth, the overall subsurface is behaving as a connected, vulnerable hydrologic system in which contamination at one level can influence adjacent levels.

Taken together, the geoelectrical evidence points to a dual contamination scenario: (1) shallow ferruginous contamination that has lowered resistivity and is intruding downward into the aquifer, and (2) a deeper, laterally extensive saline intrusion that lowers resistivity within a specific spread and extends to greater depths. The co-existence and continuity of these conductive anomalies make the aquifer highly vulnerable to further degradation and reduce the availability of potable groundwater without treatment or remediation.

Summary and Conclusions

The ERT tomogram reveals (a) a shallow, low-resistivity zone interpreted as an iron-water (ferruginous) formation whose conductivity increases as it intrudes downward, and (b) a deeper, continuous low-resistivity body interpreted as saltwater intrusion spreading laterally and vertically. Both anomalies are continuous with depth and indicate a single, highly vulnerable subsurface system where freshwater quality is being compromised.

In conclusion, it shows that:

Shallow aquifer horizons show clear geoelectrical evidence of iron-rich groundwater (resistivity drop → higher conductivity).

A deeper, continuous low-resistivity zone is consistent with saltwater intrusion penetrating the aquifer to greater depths.

The aquifer system is highly vulnerable: conductive anomalies are continuous with depth and threaten potable water supply.

Immediate interventions are required: controlled abstraction, targeted borehole relocation (avoid conductive zones), regular hydrochemical monitoring, and consideration of artificial recharge or barrier measures to limit further saline encroachment.

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