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Research Article

Delineation of Saltwater Intrusion in Coaster Aquifer of Akuku - Toru Local Government Area of Rivers State, Nigeria

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ABSTRACT

Vulnerability of groundwater aquifer to saltwater intrusion cannot be ruled out in any coastal part of the world. Naturally, underground water flow (hydrodynamic) often plays a major role in the saltwater intrusion of the coastal aquifers, which poses a threat to the availability of quality drinking water to the people in the community. Less attention had been given to the issue of saltwater infiltration into freshwater aquifers in Akuku-Toru Local government area of Rivers State, Nigeria such that lack of access to freshwater in the area is now becoming a major concern. Hence, this work delineated the saltwater intrusion problem in a coastal aquifer in the study area with the aim of making useful information available about the hydrogeology of the area. Electrical resistivity imaging (tomography) profiling was adopted with Schlumberger array configuration. The electrode spacing ranged from minimum spacing "a" to maximum spacing "6a" and inverted sections were generated using RES2DINV. The inverted section showed the top soil and an underlying clayey soil. Relative to the control units, the average top soil resistivity exhibited a reduction of 37 to 96% while the underlying clay section showed a decreased resistivity of 99%. The result thus, suggested saline water invasion of the top soil and critical invasion of the clayey layer of the study area.

Keywords: Coastline; Infiltration; Resistivity; Saline water

INTRODUCTION

Saltwater Intrusion into coastal aquifers is a common phenomenon in the coastal areas of Nigeria such that most boreholes drilled yielded saline water, which has resulted in hampered potable water availability in most of the areas. This development affects a large number of communities along the over 1000 km long Nigeria's coastline with the Atlantic Ocean. Of course, saltwater intrusion into the freshwater aquifer is a common problem in coastal areas all over the world and the saline intrusion into the coastal aquifers had thus been described as a major concern [1]. In fact, notable environmental problems have been ascribed to saline water intrusions into coastal aquifers [2,3]. For example, saltwater intrusion problem was investigated in South Korea where it was observed that fresh groundwater salinization is associated with groundwater withdrawal [4].In Rhodes Island, USA the deterioration of freshwater quality as a result of the natural seawater infiltration was identified by Frohlich and Urish as having effect on the balanced life of the narrow coastal strip [5].

Coastal impact assessments of groundwater had been carried out by some researchers in parts of these communities with the aim of assessing fresh water resources [6]. Related researches, which have given better understanding of the saline intrusion, had helped the government and its agencies to make good policies on coastal water resources management. In Nigeria, a lot has been done by Lagos state on hydrogeological evaluation of its ground water resources especially in the coastal areas. Individual university researchers have also ventured into various works on the subject matter in the state. For example, carried out 2-D resistivity imaging in other to determine the groundwater conditions around Iwaya area of Lagos. The result of the study revealed a high resistivity contrasts between the saturated

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freshwater zones and low resistivity of the saturated saltwater intrusion zones. Also, carried out geophysical investigation of saline water intrusion into freshwater aquifers at Oniru, Lagos State. The results had it that saline water plumes occurring in different part of the study area. The 2-D resistivity result showed the saline water intrusion between a depth of 13 and 64 m [7].Carried out integrated geophysical and geochemical investigations of saline water intrusion in a coastal alluvial terrain, south-western Nigeria. The depth of inverse models from the geoelectrical resistivity data obtained in the area revealed significant impact of the saline water on delineated aquifers with very low resistivity values uniquely below 4.0 Ω m. Is also a good reference in Port Harcourt, existence of saltwater zone was identified by at a depth of 30 m at and 120 m at Eastern by-Pass areas of the city. Using 2-D electrical resistivity imaging, the authors identified the low resistivity zones as the saltwater intruded zones.

Electrical resistivity method is a very effective technique of studying the environmental impact assessments of groundwater pollution. Several studies have been carried out around the world on groundwater pollution, quality, direction of flow and flow rate using resistivity technique. In locating the groundwater pollution and monitoring its flow direction, used surface electrical resistivity method to carry out a field investigation. According to the investigation, there was a reduction in resistivity values as compared to the resistivity values of the groundwater of the reference station. The author described the sensitivity of the method as being dependent on the relative uniformity of the geology and topography of the area. Electrical resistivity method was also used by for the purpose of detecting subsurface fresh and saline water and delineating their interfacial configuration.

Ekinci conducted a two-dimensional electrical resistivity survey to determine layered seawater-freshwater interface in coastal alluvium of Gokceada-Turkey [8]. The interpretation of the two-dimensional inversion of the acquired resistivity data delineated the seawater-freshwater interface. It was interpreted that the freshwater has resistivity value (15-35 Ω m) exists over the denser seawater with resistivity value (0.7-3 Ω m). The seawater-freshwater interface was observed below the depth of approximately 7-8 m. Used electrical resistivity method to map possible saltwater intrusion, and fresh water interface in Lekki area of Lagos. The resistivity curves obtained from the Vertical Electrical Resistivity (VES) showed dominant trend of increasing salinity with depth. Other important works that had employed electrical resistivity technique in the study of saline water intrusion include Ahmed and Mahmoud [9].

Akuku-Toru in Port Harcourt, Niger Delta Nigeria has been described as being occupied predominantly by rural communities who depend mainly on its freshwater for drinking bathing and washing [10].The characteristic Deltas in Akuku-Toru were formed from splited River Niger in the area. The present study employed the resistivity imaging to investigate saltwater intrusion into freshwater aquifer within Akuku-Toru local government area in the coastal part of Port Harcourt, River State Nigeria.

MATERIALS AND METHODOLOGY

Study area and its geology

The study area is in Akuku-Toru Local Government Area of Rivers State, Niger Delta Southern Nigeria, which is located between latitudes 4°43'25"N and 4°21'24"N, and longitudes 6°37'15"E and 6°50'56"E. It is marked by two distinct seasons, the dry season and the rainy season. The dry season lasts from about November to April and while the rainy season spans May to October with a brief dry spell in August. The study area has characteristic tropical equatorial climate with mean annual temperature of 32.8ºC and annual rainfall of 2673.8 mm. Located in Benin Formation, Akuku-Toru is typically riverine and has a large number of outlets through which her tributes from River Niger empty their water into the Atlantic Ocean. It is predominantly sandy with a few intercalations of shale beds. The sands are always unconsolidated, granular in texture and characteristically fine to coarse grained size and described as fresh water bearing. At various depths in the formation, both confined and unconfined aquifers are encountered (Figure 1-3).

In this study, electrical resistivity imaging (tomography) profiling was adopted for the subsurface aquifer investigation due to saltwater intrusion into freshwater aquifer. The geophysical equipment used is the ABEM Terrameter 300 C with a Signal Averaging System (SAS), a method whereby consecutive readings are taken automatically and the results are averaged continuously.

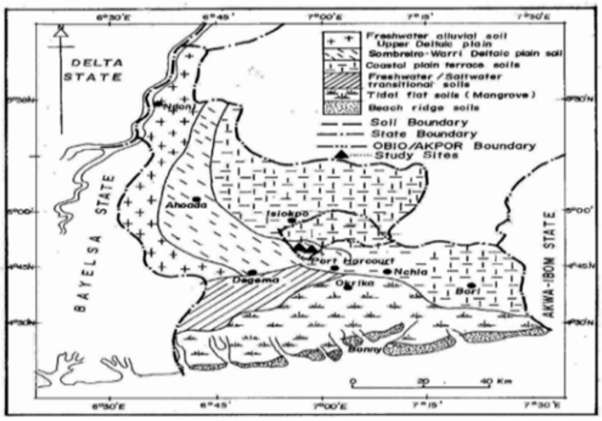

Figure 1: Location map of the study area.

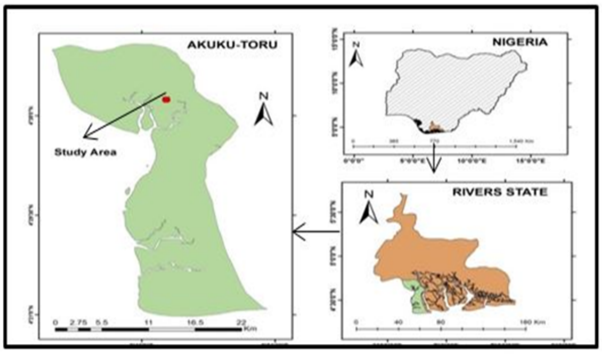

Figure 2: Nigeria coastline.

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A total of eight profile lines were established for the 2-D resistivity survey. For this study, electrical resistivity Wenner imaging was adopted [11]. A 200 m multicore cable with a 10 m take-out interval for Profile 1 and Profile 2 and 100 m multicore cable with a take-out interval of 5 m for Profile 3, Profile 4, Profile 5, Profile 6, Profile 7 and Profile 8 were used. Profile 8 was chosen to serve as the reference profile. After taking the first reading at station one, the cables were moved in a leap-frog manner to the next position of electrodes 2,3,4 and 5 for the second station reading. This procedure was repeated until spacing of 2a, 3a, 4a, 5a and 6a was acquired. A total of 504 measurements points were occupied for the eight profiles during the 2-D resistivity survey.

The eight resistivity profiling data obtained from the field were processed using a 2-D iterative smoothness constrained least square inversion technique to create a subsurface model of the resistivity by inverting the apparent resistivity data. The inverted sections were generation was done using RES2D inversion software.

RESULTS AND DISCUSSION

The nature of the fluid present in the pores of a rock greatly influences the resistivity of the lithology. To ascertain the extent of pollution, the resistivity depth section from polluted segment of the study area was compared with the background value of the control section.

The inverted section of profile 8, which is the reference profile, indicated two sequences, which were the top soil and the clayey units. The top soil exhibited high electrical resistivity values ranged from 146 to 665 and extremely high values ranging from 665 to 3039 Ω m. It occurs from the surface to a depth of about 4.78 m. The clayey layer, which underlined the top soil exhibited resistivity values between 15 and 146 Ω m and occurred up till a depth of about 11.9 m. This indicated that the unit is still a fresh water-bearing zone. The low resistivity zone mostly characterized by the salt water was absent in the profile. The quality and quantity of water influence the resistivity of a medium more [12].

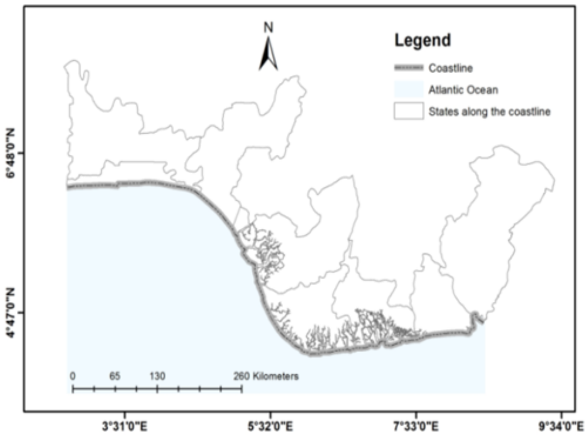

Figure 3: Generalized geological map of rivers state.

In profile 1, the inverted resistivity section showed the top soil occurring from the surface to depth of about 13.9 m with the high resistivity ranging from 92 to 300 Ω m and extremely high value ranging from 300 to 1032 Ω m. When compared to the low resistivity of the top soil of profile 8 (reference profile), the percentage reduction in the low resistivity was 37%. The high resistivity observed within this zone could be associated to the presence of sand. The clay unit exhibited electrical resistivity value from 15 to 92 Ω m and occurred from a depth of about 5.63 to 29.7 m. Its comparison with the reference lithology gave a very significant resistivity reduction of 0%. This showed the absence of salt water in the zone, which covered almost the entire profile [13].

The top soil of profile 2 is characterized by two disjoint high resistivity zones with an intermediate very shallow resistive section. The resistivity ranged between 68 and 387 Ω m to a depth of about 18.5 m. The two high resistivity zones occurred at about 73 m apart. The underlying clay unit had electrical resistivity value between 19 and 68 Ω m. 53% reduction in the resistivity value was obtained for the top soil while 21% resistivity increase was obtained for the second layer compared to the reference value. Saltwater seemed not to have intruded the profile [14].

Inverted resistivity section of profile 3 showed that the top soil, which was to a depth of about 6.8 m had a resistivity values ranging from 22 to 390 Ω m. Comparing the lower resistivity to the lower resistivity of the top soil of the reference profile gave 85% resistivity reduction. The second section of the profile was characterized by electrical resistivity value in a range of 3–22 Ω m. Electrical resistivity value reduction of 80% was obtained in the layer. This indicated a highly conductive zone, which had occurred as a result of saltwater infiltration. The second section of profile 4 (electrical resistivity ranged between 14 and 60 Ω m) had 6% resistivity reduction, which is an indication that saltwater infiltration was not noticeable [15].

Similar to the top soil of profile 2, two disjointed zones of high resistivity (>395 Ω m) could be delineated in profile 5 with both zones exhibiting a prograding attribute in terms of depth up till about 10.0 m [16]. The low resistance of this layer had 79% reduction when compared to the reference profile. The second layer, which occurred from a depth of about 7.97 to 14.3 m exhibited a section of low resistivity (2–30 Ω m) that runs between 45 and 65 m along the profile. The low resistivity value represented 86% electrical resistivity reduction. The saltwater was observed to be intruding in the NE-SW direction [17].

Top soil of profile 6 exhibited high resistivity value (up to 886 Ω m) while the underlying clayey layer exhibited extremely low electrical resistivity ranging from 0 to 5 Ω m. The high resistivity zone in the top soil was to a shallow depth of about 7 m and continued in the second layer to a depth of about 17.1 m. The extremely low resistivity in the second layer represented 100% reduction in electrical resistivity when compared to the reference profile and it occurred from a shallow depth of about 8.0 to 17.1 m. Thus saltwater intrusion from NE-SW direction had highly polluted the zone [18].

The inverted resistivity section of profile 7 showed a top soil of high electrical resistivity values ranging from 65 to an extremely high resistivity value of 3066 Ω m and to a depth of about 11.9 m. The profile was also characterized by a clay layer of extremely low resistivity zone of 1–65 Ω m. This gave 93% resistivity reduction, which indicated saltwater intrusion into the zone [19].

CONCLUSION

Effectiveness of electrical resistivity imaging in subsurface material delineation cannot be over emphasized. The present study adopted the technique, using Wenner imaging and Schlumberger array to examine the extent of saltwater infiltration in Akuku-Toru Local government area of Port Harcourt, Niger Delta Nigeria. Top soil overlying a clayey layer was observed from the 2-D inverted sections. The resistivity of the unaffected section of the study area was compared with the resistivity of the affected sections for the purpose of saline water infiltration confirmation. The inverted section showed that the top soil of profiles had been invaded by the saline water with the top soil of profile been critically affected. The conductive second layers of profiles showed comparable resistivity values to the unaffected layer. Thus saltwater is absent in the zones, while profiles had been critically invaded by the saltwater.

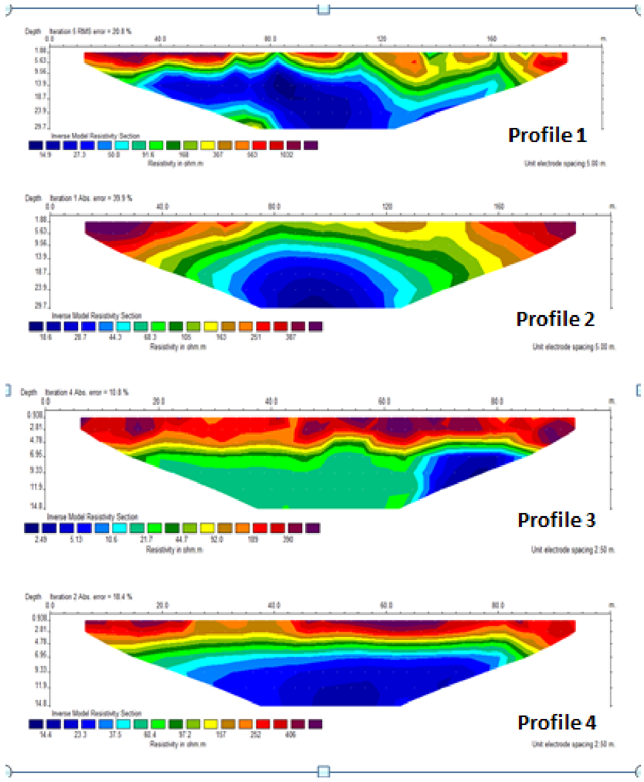

Figure 4: Resistivity plot for profiles.

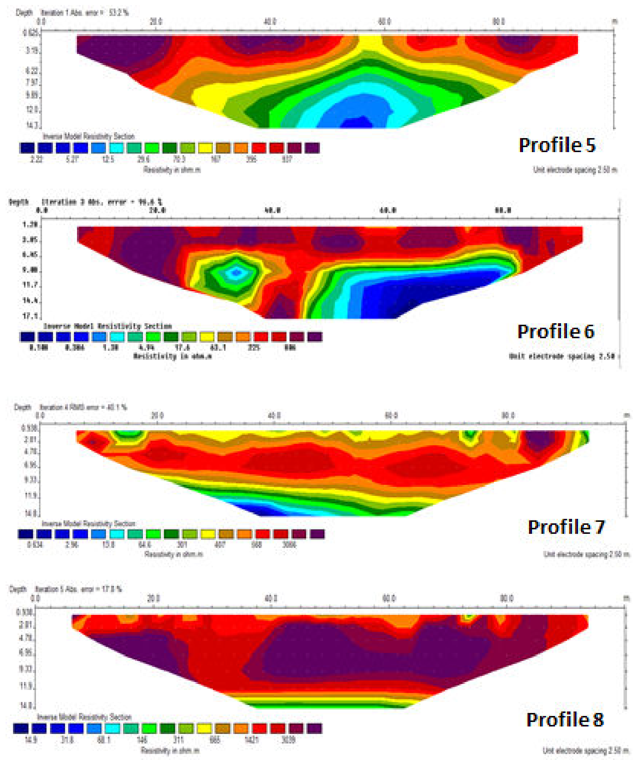

Figure 5: Resistivity plot for profiles.

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