

## **Saltwater Intrusion into Coastal Aquifers in Nigeria**

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### **ABSTRACT**

Nigeria has a long coastline with the Atlantic Ocean. Coastal Nigeria is covered by two sedimentary basins - The Benin and the Niger Delta basins. The aquifers are sands with intervening impermeable clay layers giving rise to multi-aquifer systems. Salt water intrusion into unconfined and confined aquifers has occurred in both basins and many boreholes have been abandoned while development of potable water for the communities is hampered by salt water intrusion. Detailed studies to demarcate the interface has only been carried out in parts of the coastal areas. In the western part of the Benin basin, saltwater intrusion has only been found in the unconfined aquifer. In the central and eastern parts however, intrusion into the unconfined and confined aquifers have occurred with saline water overlying fresh water. The Benin Formation and the Niger Delta Basin consisting of massive highly porous sands and gravels forms a multi-aquifer system. The unconfined aquifer in the coastal beach ridges has a fresh water lens overlying salt water. The confined aquifers in most parts of the delta contain fresh water underlain by salt water. In certain zones of the delta however, salt water intrusion into the confined aquifers has occurred with salt water - bearing sands overlying fresh water - bearing sands. These are in turn underlain by saltwater - bearing sands. The depth to the same saline water - fresh water interface is found to vary from one place to the other being as high as 947m below ground level. A vast majority of the abandoned boreholes in the Niger Delta are within these zones.

Various constraints have been found in the development and management of groundwater resources in coastal aquifers in Nigeria. These include:

- X Lack of adequate knowledge of the nature of the salt water intrusion.
- X Uncontrolled development of both unconfined and confined aquifers in industrial centers such as Lagos, Port Harcourt, Warri and Bonny.
- X Lack of proper sealing of abandoned or disused boreholes
- X Poor access of rural indigenous communities in coastal areas to potable water supply due to perceived lack of fresh water resources in these areas. These are the oil producing areas of Nigeria whose access to potable water supply is below the national average. This fuels restiveness and disaffection to oil exploration and production activities by multinational and national companies.

Detailed studies to determine the hydrogeology of the coastal basins and the nature as well as extent of salt water intrusion are a prerequisite in the prevention of further salt water intrusion and are urgently required.

## **INTRODUCTION**

Nigeria has a coastline that is about 1000km long with the Atlantic Ocean, bordering eight states. These are Lagos, Ogun, Ondo, Delta, Bayelsa, Rivers, Akwa Ibom and Cross River States. While the first four states are west of the River Niger, the last three states are east of the Niger with the last Bayelsa State, straddling the river (Figure 1). Potable water supply to inhabitants in some of the communities in the coastal belt has been a major problem due to salt water intrusion. Communities such as Burutu in Delta State and Aiyetoro in Ondo State have no potable water source as the surface water is salty while all the boreholes drilled so far have yielded saline water. The inhabitants therefore depend on rain harvesting (in the midst of numerous gas flares from oil production platforms) and purchasing water from merchants coming from the hinterland in boats. Since the mid-'80s, many potable water programs have been carried out in Nigeria based on the development of groundwater by the Federal Government and its agencies, States and multi-lateral agencies such as UNICEF and UNDP. Unfortunately many communities in the coastal belt are not benefiting due to perceived difficulties as a result of salt water intrusion. In this paper, a review of the geology of the coastal basins is given followed by a description of the nature of salt water intrusion. The paper is concluded by discussing the constraints to the development and management of potable water in the coastal areas in Nigeria.

## **GEOLOGY AND HYDROGEOLOGY**

Coastal Nigeria is made up of two sedimentary basins: The Benin basin and the Niger Delta basin separated by the Okitipupa ridge (Figure 1). The rocks of the Benin basin are mainly sands and shales with some limestone which thicken towards the west and the coast as well as down dips to the coast. Recent sediments are underlain by the Coastal Plains Sands which is then underlain by a thick clay layer - the Ilaro Formation and other older Formations (Jones and Hockey, 1964). The Recent Sediments and Coastal Plains Sands consist of alternation of sands and clays. The Recent Sediments forms a water table aquifer which is exploited by hand-dug wells and shallow boreholes. The Coastal Plains Sands aquifer is a multi-aquifer system consisting of three aquifer horizons separated by silty or clayey layers (Longe et al. 1987). It is the main aquifer in Lagos Metropolis that is exploited through boreholes for domestic and industrial water supply. In the coastal belt of the Benin basin, this aquifer is confined.

The Niger Delta is a coastal arcuate delta of the River Niger covering an area of about 75,000km<sup>2</sup>. The subaerial Niger Delta has an extensive saline/brackish mangrove swamp belt separated from the sea by sand beach ridges for most of the coastline. Water supply problems relating to salinity are confined to the saline mangrove swamp with associated sandy islands and barrier ridges at the coast. Geologically, rocks of the Niger Delta are

subdivided into three Formations which are Akata, Agbada and Benin Formations (Short and Stauble, 1967). The Benin Formation consisting predominantly of massive highly porous sands and gravels with locally thin shale/clay interbeds forms a multi-aquifer system in the delta. Many boreholes have been drilled into the aquifers of the Benin Formation yielding good quality water but many have also been abandoned due to high salinity. Oil and gas are produced from sand reservoirs in the Agbada Formation while the Akata Formation consists of uniform shale rocks.

In the Benin basin, salt water intrusion into the Recent Sediments aquifers occurs beneath a fresh water lens in a belt stretching from the coast line to a distance of about 5km in some places. Salt water intrusion has also been found to occur in the confined aquifers of the Coastal Plain Sands in a zone stretching from Apapa to Lekki within Lagos metropolis. The salt water bearing sands overlie fresh water aquifers which are exploited by boreholes. In the eastern part of the Benin basin represented by Akodo, the fresh water aquifers in the Coastal Plains Sands are sandwiched between salt water - bearing sands. The Coastal Plains Sands in a zone between Lekki and Akodo around Lakowe estimated to be about 20 km wide consists predominantly of clay with only about 60 m of sand overlying about 240 m of clay unlike the other areas of the basin where sand represents between 70 to 95 percent of the about 300 m thick horizon. A geologic east - west cross-section along the coast shows the variation in geology and water quality in the Benin basin (Figure 2).

Saltwater intrusion into unconfined and confined aquifers also occur in the Niger Delta. In coastal beach ridges or sandy islands within the saline mangrove belt, fresh water lens floating above salt water - bearing sands are found to occur in the unconfined aquifers (Oteri, 1990). Based on the depth of occurrence of the first saline water sands in the confined aquifers of the Benin Formation, the delta can be divided into two major areas: areas where fresh water sands are encountered at shallow depth underlain by saline water sands (Group F) and the areas where saline water sands are encountered at shallow depths underlain successively by fresh water sands and saline water sands (Group S). Shallow oil well logs of some two wells from the Niger Delta illustrate these two groups (Figure 3). The Group S wells are found to occur in well-defined zones, four of such zones having been identified so far (Figure 4). In both groups, the depth to the interface varies from one place to the other. For the Group S wells near Port Harcourt, the depth to the top of the fresh water sands underlying the saline water sands was found to vary from 77 m to 947 m below ground level. Apart from these major groups, there are areas within the delta where all the sands encountered in a well contain salt water while at some other locations, multiple wedge structure in which successive aquifers separated by shale beds have their separate fresh water/saline water interfaces have been found (Oteri, 1988).

## **STATUS OF SALT WATER INTRUSION IN NIGERIA**

Delineation of salt water intrusion: Successful management of coastal ground water resources depends not only upon planning and regulation, but also on the accurate assessment and prediction of the behavior of the saltwater interface to both natural conditions

and man's activities (Yuhr and Benson, 1995). In Nigeria, there have been few studies aimed at assessing fresh water resources in coastal areas of the country and most of these have been by university researchers. Of all the Federal and State Water Agencies, Lagos State has done the most with state - wide hydrogeological evaluation of its ground water resources including coastal areas (Kampsax - Kruger and Sshwed, 1977; Coode Blizard Ltd. et al 1996). It has benefited with a large scale development of potable water in all areas of the State. Governments and water agencies in the other coastal States including the Federal Government have been averse to such studies. It is no wonder that the other coastal areas especially in the Niger Delta have not benefited maximally from the various water supply projects carried out since the 1980's. Hence the inhabitants of these rural coastal communities which are the oil producing areas of Nigeria continue to suffer from lack of potable water. The high degree of restiveness and agitation against oil companies and installations is partly due to the lack of basic infrastructure in their areas especially potable water.

**Monitoring and Management:** There is no monitoring of salt water intrusion in Nigeria. This is compounded by unwholesome practice such as:

- 1 Uncontrolled development of both unconfined and confined aquifers especially in Lagos Metropolis, Port Harcourt, Warri and Bonny. In Lagos which is the commercial capital of Nigeria, the problem is particularly acute as many boreholes which were producing fresh water after drilling become salty a few months later.
- 2 Lack of proper sealing of disused boreholes or those abandoned due to salt water intrusion.
- 3 The groundwater in most of the confined aquifers in coastal Nigeria is corrosive and casing corrosion is a major source of borehole failures. There is need to determine the best material for casing and screens and also best completion techniques that will prevent salt water ingress into fresh water yielding boreholes especially in situations where the fresh water aquifer underlie saline water-bearing sands.

## **CONCLUSION**

Salt water intrusion into aquifers in the coastal sedimentary basins in Nigeria has occurred. Mapping of the fresh water/salt water interface(s) in most of the coastal aquifers is yet to be carried out, thereby making it difficult for many of the communities to be provided with fresh potable water. Monitoring and management of salt water intrusion is also not done. There is a great and urgent need for all stakeholders in Nigeria's coastal region to appreciate the phenomenon of salt water intrusion and commission the necessary studies to

delineate, monitor and manage the fresh water resources of the coastal areas to the benefit of its people and industry.

## **Referees**

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## **FIGURE CAPTIONS**

Figure 1: Geological sketch map of Nigeria showing the coastal basins.

Figure 2: West - East hydrogeological cross - section along coastal area of Lagos State.

Figure 3: (a) Schematic diagrams showing characteristics of Group S and Group F  
wells

(b) Electric logs of well - 1 and well -2, examples of Group S and Group F wells respectively. ( $R_m$  = resistivity of mud;  $R_{mf}$  = resistivity of mud filtrate, Resistivity in  $\Omega m$ ).

Figure 4: Map of Niger Delta basin showing coastal areas where saline water sands overlie fresh water bearing aquifers.