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ASSESSMENT OF GROUNDWATER QUALITY AND SALTWATER INTRUSIONS IN COASTAL AQUIFERS IN AYETORO COMMUNITY, ONDO STATE NIGERIA

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ABSTRACT

Ayetoro, a coastal community in Ondo State, Nigeria is currently facing a saltwater intrusion that puts its survival at risk. This study analyzed (10) water samples from Ayetoro community's coastal aquifers to evaluate groundwater quality, saline intrusion impact, and conduct different physicochemical analysis. This paper discusses multiple causes of saltwater intrusion, such as the excessive use of freshwater and climate change, along with necessary methods for managing saltwater intrusion and the consequences it brings to coastal areas, the environment, and groundwater contamination in the region. The results were compared with the acceptable drinking water limits set by the World Health Organization (WHO). The findings showed that pH levels vary from 5.28 to 6.59, suggesting that the analyzed water samples may pose a threat to human health (such as skin irritation). The total hardness levels indicate that all water samples exceed the WHO's permissible limit of 500. High electrical conductivity values were observed in all water samples except for AY_9, indicating a likely presence of saline water intrusion in the groundwaters of Ayetoro community. Nonetheless, the levels of sulphate, chloride, sodium, potassium, total dissolved solids (TDS), and calcium-related hardness remained within acceptable limits for domestic use and irrigation in the entire study area, except for drinking water. Thus, it is advised to conduct consistent monitoring of saltwater intrusion to prevent contamination of other aquifers.

Keywords: Physiochemical Analysis, Saltwater Intrusion, Groundwater Quality, Coastal Aquifers, Ayetoro Community.

I. INTRODUCTION

Groundwater has served as a main source of drinking water and irrigation for a lengthy period and continues to be essential in present times. The progress of groundwater has resulted in significant socioeconomic benefits for society. Globally, approximately half of the current water supplies for drinking and irrigation are thought to originate from groundwater. Because groundwater is distinct from the surface, some people believe it should be clean and free of contamination. Although most of the groundwater is still of good quality, maintaining its purity in specific regions is becoming increasingly difficult. Saltwater intrusions contaminating groundwater are a major contributor to pollution. Other sources of pollution also encompass spills from underground storage tanks, offshore oil platforms, septic systems, landfills, and the leakage of chemicals from farms. Excessive pumping of groundwater in coastal areas causes saltwater intrusion as seawater infiltrates freshwater aquifers [1,2,3,4,5].

Researchers believe that a significant number of people around the world live close to the coast [6,7]. As outlined in reference [8], around 10% of the Earth's surface is taken up by the coastal area. Consequently, the coastal aquifers are being subjected to increased pressure, leading to an elevated risk of saltwater intrusion (fig.1). Monitoring the level of saltwater intrusion in groundwater is essential. The infiltration of saltwater into aquifers along coastlines is currently a major concern because it is the main reason for groundwater contamination. The amount of saltwater that gets into groundwater is determined by a combination of natural and human factors, with the aquifer's attributes and recharge speeds as the key natural elements. Even a small quantity of seawater can contaminate freshwater, underlining the urgency to find a solution for this issue [9]. The complications associated with saltwater intrusion are multifaceted. Urbanization causes groundwater depletion, disrupting the fragile hydrogeological equilibrium, exacerbating the issue [10].

Saltwater intrusion is a well-known problem worldwide, leading to significant research efforts at various levels [11]. Research conducted in Nigeria has documented instances of seawater encroachment in coastal aquifers, spanning from Lagos State to Cross River State [12,13]. However, it is essential to conduct a comprehensive examination at the ayetoro community level to understand the unique challenges and causes of controlling saltwater intrusion. Ondo State, Nigeria, situated by the Atlantic Ocean, faces unique challenges due to its coastal position. The reliance of the community on underground freshwater is hindered by the risk of encountering saltwater while drilling boreholes [9,14]. However, it is possible to use the electrical conductivity of groundwater to identify

intrusion, as increased values indicate the presence of seawater infiltration [12,15]. Groundwater salinity is mainly caused by the dissolution of chloride minerals [16].

The goal of the current research is to assess the groundwater quality in the coastal regions of Ayetoro, Ondo state, and assess the extent of saltwater intrusion in the coastal aquifers of the area. Sampling sites were selected along the coast where groundwater samples were collected and assessed for their physical and chemical characteristics.

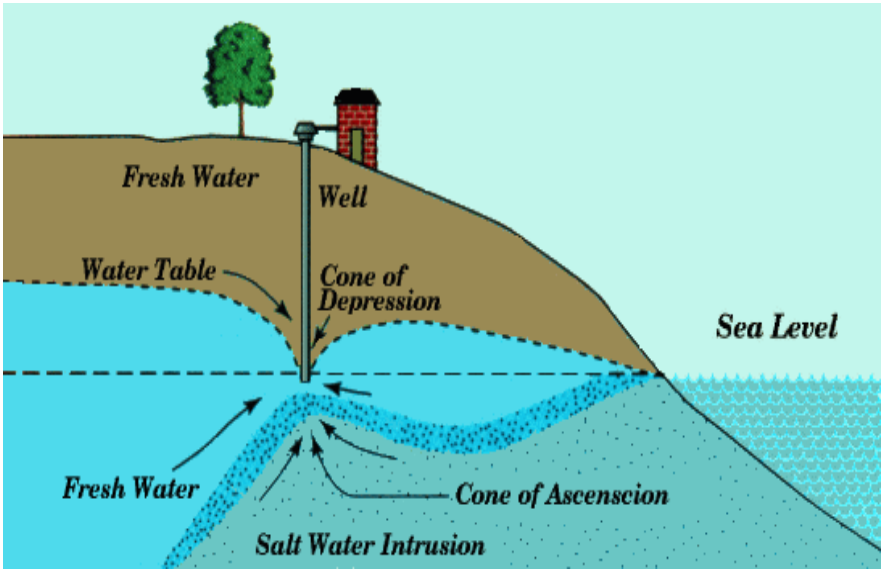

Fig 1. The Schematic diagram of freshwater-saltwater transition zone in an idealized coastal aquifer.

Fig 2. Intrusion of water salinity in fresh land and its impact on vegetation loss in the coastal region.

II. THE STUDY AREA

Ayetoro is a significant fishing village in Ilaje Local Government of Ondo State, located in Southwest Nigeria, situated between Latitudes 05°16' and 06°30' North and Longitudes 04°45' and 05°45' East of the Greenwich Meridian (Fig. 3). The area is famous for its abundance of seafood such as crabs, periwinkles, crayfish, and various types of fish. Hence, the infiltration of seawater, flooding, and deterioration of land in the area poses a significant issue for both national and global food security as well as public health (fig. 2). The intrusion of the sea and forced relocations caused by high tides and severe waves, which negatively impact the residents' livelihood, can result in significant economic losses due to the decrease in agricultural output, particularly in fishing, the main source of

income for the Aiyetoro community. More than 30% of the land in Ayetoro community and surrounding areas has been deserted, with around 2km of the Ilaje coastal waters already impacted by sea incursion and flooding. The study area is located in a region with multiple rivers flowing into the Niger River and reaching the Atlantic Ocean. It includes various streams and inlets along with a still mangrove swamp and around 2.0 km of shoreline. Land subsidence causes the topography of Ayetoro area to decrease in relation to the sea, increasing its susceptibility to rising sea levels. In coastal regions, the significance of the relative sea level rise outweighs that of the eustatic sea level rise. Despite the worldwide average eustatic sea level rise of 3mm per year, the Niger Delta region in Nigeria and surrounding areas experience a relative sea level increase with subsidence rates ranging from 25 to 125mm per year, leading to increased susceptibility to flooding. Climate change is expected to create increased energy waves that affect the coastal areas. As a result, ocean surges happen due to the periodic overflow and sudden crashing of large sea waves, leading to flooding in coastal communities. Hence, wave characteristics and height must be considered in Oceanographic engineering solutions.

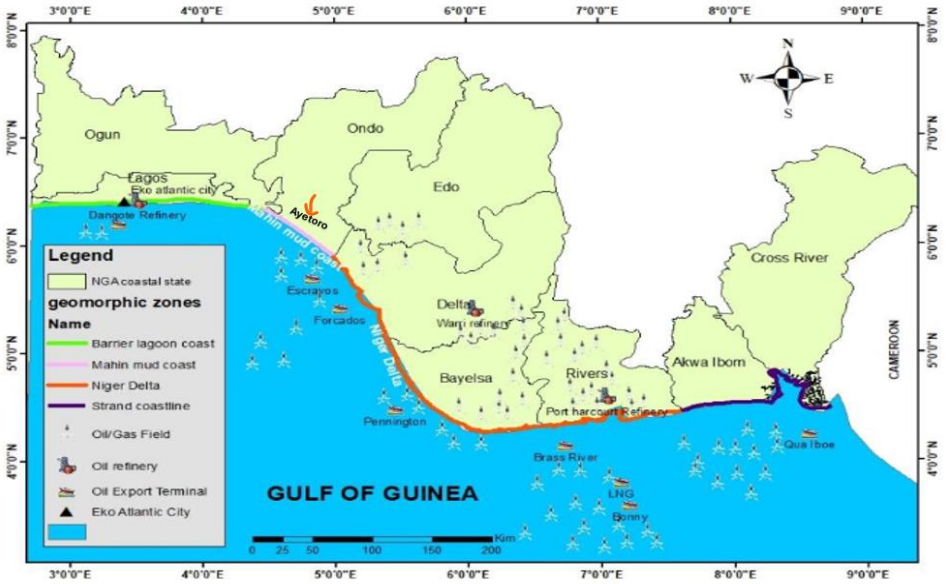

Figure 3. Costal facilities along the Nigeria coast.

III. METHODOLGY

Groundwater samples were gathered from ten (10) distinct locations (wells) in the coastal regions of the Ayetoro area in Ondo State. Samples were collected after pumping the wells for ten (3) minutes to ensure accurate sampling and to conduct physicochemical analyses. In-situ measurements were taken for pH, temperature, and electrical conductivity using suitable instruments, while flame absorption spectrophotometry was utilized to determine alkali metals. The sampling sites' locations are indicated in Figure 3. We examined the hydro-chemical data we collected and compared it to the permissible limits set by WHO to see if the concentrations meet the standards.

pH was measured with a pre-calibrated pH meter. The specific conductance of electricity was determined with a Horiba U90 meter, accurate to 0.001 µs/cm. Standard methods were used to measure the total dissolved solids, total hardness, sulphate, alkalinity, and chloride [17,18]. Sodium and potassium in alkali metals were analyzed using flame absorption spectrophotometry. All chemicals of analar grade were prepared to use for analysis. Reagent blanks were appropriately prepared for every analysis.

IV. RESULTS AND DISCUSSION

The analyses of ground water samples showed that some parameters were within the allowable limits set by FEPA [19], and WHO [20].

The pH levels of the groundwater varied between 5.28 and 6.59, indicating it fluctuated between high acidity and mild alkalinity. Per WHO guidelines, the optimal pH level for drinking water falls within the range of 6.5 to 8.5. Every sample in this range displays unsuitability for domestic and agricultural use because of their volatile acidity levels. This could pose a risk to the health of individuals such as skill irritation and corrosion of iron materials.

The combined hardness of the water samples surpasses the allowable limits as specified in Table 1 by regulatory agencies. Total hardness measures the combined presence of calcium, magnesium, and other polyvalent cations like iron, zinc, manganese, aluminium, and strontium. The small amount of calcium in the total hardness could indicate that there

are no calcium-bearing minerals in the aquifer below. The elevated levels of overall hardness could be a result of polyvalent cations being added to the groundwater system which may cause kidney stones if too much of it is being consumed. The results from [21] showed that the water samples from all the chosen wells have a Ca^{2+} hardness percentage of 100%, indicating that they are all very hard. Across our research sites, there is a significant amount of total hardness present, measuring ≥300 mg/l.

Table 1 shows TDS levels ranging from 534 to 1241 mg/L. It is a method of assessing the overall quantity of inorganic and organic substances present in water. TDS levels below 1000 are classified as suitable for watering plants and will not affect the osmotic pressure of the soil solution [22]. This suggests that the water samples in the study area are suitable for irrigation and recommended for other domestic uses, although not for drinking.

The elevated levels of electrical conductivity along the coastal areas of the research site indicate that there is connection between the ocean and the aquifer in that area. This indicates a strong likelihood of saltwater seeping into most of the water-bearing layers in that area because of its proximity to the Atlantic Ocean (Table 1). These increased conductivity readings suggest that the water has been in extended contact with ocean water, leading to saturation in terms of saltwater intrusion.

The samples' chloride concentration did not surpass the WHO limit of 250mg/L. Chloride is not deemed dangerous for humans; however, it gives water a saltier taste when present in high amounts. The elevated levels of chloride found in this research could potentially be damaging to plants when utilized for watering crops. Reported damages to plant tissues have been associated with chloride levels reaching up to 70 mg/L [23]. The levels of sodium and potassium, alkali metals, differed greatly. Sodium levels varied from 98.7 to 481.5 mg/L whereas Potassium levels varied from 58 to 320mg/L.

The levels of sulphate SO_4^{2-} and calcium hardness in the study area are within the recommended values for drinking water according to the guidelines from WHO (Table 1).

The saline waters are causing pollution and putting pressure on the groundwater in Ayetoro thereby put human health and agriculture at risk. The area is characterized by its nearness to the sea, its low elevation relative to sea level, and its inadequate aquifer structure, which is part of the Benin basin where saltwater-bearing sand sits above fresh water [24]. This could be explained by the area's close distance to the ocean.

Table 1. Hydro-chemical parameters of the study areas

Samples	pH	TDS (mg/l)	EC (µS/cm)	TH (mg/l)	Na^+ (mg/l)	Ca^{2+} (mg/l)	K^+ (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)
AY_1	6.02	1020	1241	701.7	152.2	118.7	86.3	84.3	42.2
AY_2	6.1	978.9	1210	681.3	232	121.1	36.05	58.4	41.1
AY_3	5.89	1214	1520	522	181.5	131.2	172	24.5	31.8
AY_4	6.42	534.2	1182	1201	111.5	98.7	320	28.7	23.8
AY_5	6.59	576	940.5	978.5	130.1	65.8	115	17.3	59.7
AY_6	6.45	850.7	1324	1087	210	44.1	98.2	81.8	29.9
AY_7	5.98	1152	1286	878.1	157	81.7	58.1	101.3	34.1
AY_8	5.28	985.3	1512	528.1	98.7	180.2	112	61.5	43.7
AY_9	5.78	880	803	1002.1	123.5	177.8	101	43.7	51.6
AY_10	6.49	1237.2	1237	698.7	140.8	191.5	121.8	71.3	40.8
WHO	**6.5-8.5**	**1500**	**900-1200**	**500**	**200**	**200**	**--**	**600**	**400**

V. AQUIFER SUSTAINABILITY AND MANAGEMENT PROCEDURES

If fresh groundwater is pumped out of the ground at a faster rate than it is refilled, the water table decreases, which is called drawdown in the hydrological system on land [25]. In coastal regions, the lowering of water levels, in addition to a reduction in hydrostatic pressure, results in the infiltration of saltwater from the ocean into the freshwater aquifer [25] (fig. 1). This occurrence is noted not just in the coastal areas of Ayetoro community in Ondo State, Nigeria but also in various coastal regions around the world. The result of this intrusion is the pollution of freshwater sources with saltwater (Fig. 4).

According to reference [26], there is insufficient monitoring of saltwater intrusion and some of the activities that lead to the issue in coastal areas of Ondo State, Nigeria include:

1) Uncontrolled growth of limited and unrestricted aquifers.

2) Improper sealing of decommissioned wells caused by saltwater infiltration.
3) Insufficiently finished boreholes and lack of protection against corrosion are major problems, especially when the freshwater aquifer is below sandy layers with salty water.

VI. TECHNIQUES FOR MANAGING AND CONTROLLING SALTWATER INTRUSION

Saltwater intrusion is the infiltration of saltwater into freshwater aquifers or surface water sources. Human activity, such as the excessive use of freshwater resources, climate change, and rising sea levels, is the main factor leading to saltwater intrusion [28]. Saltwater intrusion may result in major environmental and economic issues such as lower water quality, harm to ecosystems, and financial losses in agriculture and industry. As a result, it is crucial to manage the invasion of saltwater to secure freshwater resources and safeguard the environment [28]. Various methods, such as physical, chemical, and biological approaches, can be utilized to manage and control saltwater intrusion.

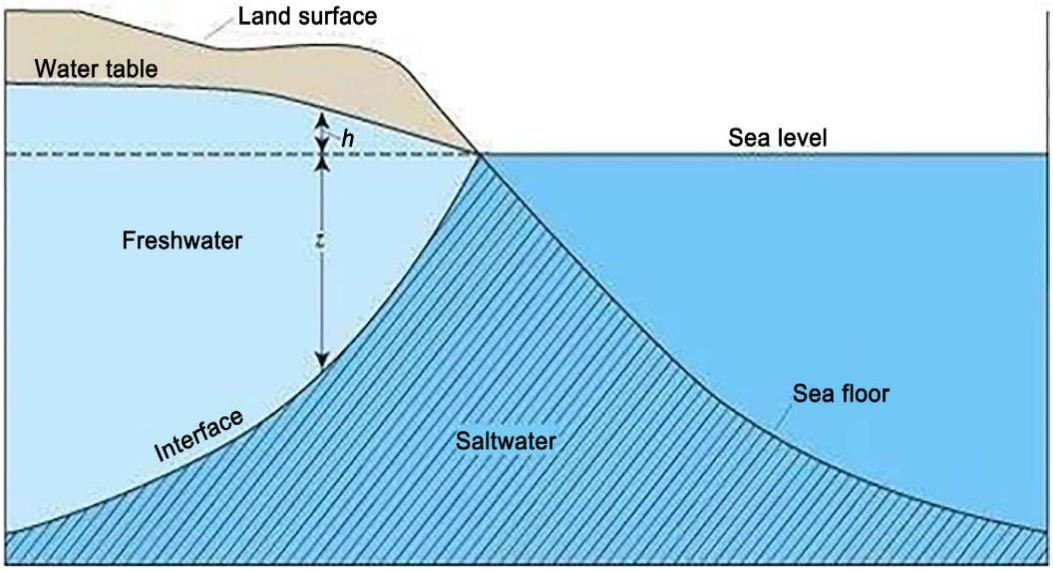

Figure 4. Concept of saline water intrusion [27].

VII. CONCLUSION

The primary purpose of this study was to examine saltwater intrusion in the Coastal areas of Ayetoro town, Ondo State, Nigeria. Knowing that salinization of wells in this area is primarily due to inadequate management and elevation of the wells is crucial. The increased electrical conductivities observed in coastal samples, along with other physio-chemical analyses, suggest that saltwater intrusion is the cause of salinization in these wells. The primary reason why wells in other areas become saline is because rock salt is dissolved in the soil layer.

The results outlined in this study show that saltwater intrusion is currently happening in the aquifers located near the ocean in Ayetoro community. The coastal aquifers in Ayetoro face various groundwater issues such as decreasing water levels, lowered piezometric surfaces, reduced yields, and the influx of salty water from various sources. These problems present major challenges for the sustainable handling and use of groundwater resources in the area for domestic and irrigation purposes. Nevertheless, overseeing the wells in coastal areas can aid in maintaining and lowering saltwater intrusion. When fresh groundwater is taken out faster than it is replenished, it can cause saltwater intrusion and drawdown in the land's hydrological system. This occurrence can be seen in coastal regions worldwide, such as Ayetoro in Ondo State, Nigeria, where seawater infiltrates freshwater aquifers, leading to the pollution of freshwater sources with saltwater. The research also emphasizes the obstacles and factors that contribute to saltwater intrusion in coastal areas of Ayetoro. Insufficient monitoring methods, uncontrolled aquifer exploitation, and incorrect well sealing all play a role in the issue. Having effective strategies in management is essential for dealing with these concerns. In essence, a combination of these methods, customized for the unique circumstances of the coastal region, is crucial for successful control of saltwater intrusion. Effective incorporation of

delineation, monitoring, modeling, and modification elements, in addition to the use of appropriate methods, will help protect freshwater resources from the harmful effects of saltwater intrusion.

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