Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 9, September 2024

Geospatial Assessment of Ground Water Quality At Osun State Polytechnic, Iree, Southwest Nigeria

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Abstract—**Groundwater is a critical source of freshwater for domestic, agricultural, and industrial uses. As human activities and environmental changes intensify, the quality of groundwater becomes increasingly important to monitor and manage. Geographic Information Systems (GIS) offer a robust platform for analyzing and mapping groundwater quality [33] This study assessed the groundwater quality at Osun State Polytechnic, Iree, focusing on its suitability for human consumption and other uses. Water samples were collected from six hand-dug wells and boreholes, and Geographic Positioning System (GPS) and Geographic Information System (GIS) were used to map the area's topography. Samples were analyzed for physical, chemical, and bacteriological properties after the rainy season in 2023. The results revealed high temperatures, turbidity, low pH levels, and high phosphate and coliform bacteria content in some samples, making certain water sources unsuitable for consumption. Recommendations include better waste management, continuous monitoring of water sources, construction of deeper wells, and the development of a water treatment plant to ensure safe drinking water for the institution's community**

Keywords—**Groundwater quality, GIS, spatial analysis, contamination, water resources management**

I. INTRODUCTION

Water is considered the most essential natural resource upon which all life depends [12]. It can be sourced from various natural reservoirs, including the atmosphere (as rain), surface water bodies (rivers and streams), and groundwater [3]. However, rainwater and surface water are prone to contamination from human activities and are often unevenly distributed for human consumption [28]. The shortage of surface water in the coming decades, especially in sub-Saharan African countries, is predicted due to the depletion of current supplies, increased consumption, and contamination [28]. As a result, groundwater has become a reliable alternative for human use [1]. Groundwater is widely utilized in domestic, industrial, and agricultural sectors [29]; [15].

Groundwater is stored in subsurface aquifers, which consist of pore spaces or fractures in rocks or sediments. It is often the only viable source of safe water in remote areas where surface water development is not economically feasible. Unlike surface water, groundwater provides a relatively constant supply and is less susceptible to drying out under natural conditions.

It has been extensively used in irrigation, industry, urban centers, and rural communities, offering the advantage of being conveniently accessible at the point of use and generally requiring little or no treatment due to its excellent natural quality.

Groundwater forms the backbone of water supply systems in many communities, including Osun State Polytechnic, Iree. With a growing population and limited access to treated water, the reliance on groundwater, sourced from boreholes and wells, has increased significantly within the institution. However, the contamination risks from improper waste disposal, septic systems, and other human activities underscore the necessity of a comprehensive study of groundwater quality [2].

While groundwater is generally less susceptible to bacterial contamination compared to surface water, due to the filtration provided by soil and rock layers, there are still risks. Bacteria can occasionally enter groundwater in dangerously high concentrations. Furthermore, the absence of bacterial contamination does not guarantee that the water is free from other harmful substances. Groundwater often contains various minerals and organic compounds, some of which are harmless or even beneficial, while others may be hazardous or highly toxic [38]. Groundwater pollution not only degrades water quality but also threatens socioeconomic activities and public health. Groundwater quality is influenced by various factors, including geochemical processes, the quality of recharge water, surface water, and precipitation [30]; [31];[24]. The presence of organic and inorganic compounds, whether suspended or dissolved in water, determines the physicochemical parameters that are essential for water quality assessment. While some compounds may be toxic to ecosystems, others serve as nutrients for aquatic organisms or contribute to the aesthetics of water bodies. Therefore, monitoring and evaluating groundwater quality is crucial for effective water resource management.

In many arid and semi-arid regions, groundwater serves as a vital resource for drinking water, irrigation, and industrial use. However, various pollutants, such as agricultural runoff, industrial waste, and natural processes like mineral dissolution, threaten its quality. Contaminated groundwater can pose significant health risks, making monitoring and management essential. Groundwater studies at Osun State Polytechnic, Iree, are critical to ensuring water quality for health and safety. As the primary source of drinking water for both the institution and the surrounding community, groundwater is increasingly relied upon due to population growth and limited access to treated water. Assessing groundwater quality helps identify contaminants like bacteria, chemicals, and heavy metals that may pose health risks, ensuring the safety of students, staff, and residents. The proximity of wells and boreholes to potential contamination sources, such as septic tanks or improper waste disposal, makes regular groundwater monitoring essential to detect and prevent pollution [2]. Routine checks can also detect environmental changes, such as acid rain or industrial runoff, that may degrade water quality over time, allowing for early intervention and remediation efforts. Geographic Information Systems (GIS) provide an efficient method for mapping groundwater quality, enabling the visualization of spatial variations, identifying contamination sources, and supporting decision-making in water resource management [36]. This paper highlights the significance of groundwater quality, outlines methods for collecting and analyzing groundwater data, and demonstrates the potential of GIS in developing groundwater quality maps. Geographic Information Systems (GIS) are increasingly recognized as vital tools for managing and analyzing spatial data related to environmental resources, including groundwater. GIS facilitates the visualization and interpretation of complex data sets by integrating spatial and attribute data, making it invaluable for water resource management [23]; [39]. In the context of groundwater quality assessment, GIS allows for the mapping of spatial variations in water quality, identifying pollution hotspots, and assisting in decision-making processes for sustainable resource management [6]. Using GIS, various layers of information—such as land use patterns, proximity to potential pollution sources (e.g., septic tanks, landfills), and water table depth—can be combined to assess the vulnerability of groundwater to contamination [24]. This multi-layered approach provides a more comprehensive understanding of how different environmental factors interact and influence groundwater quality. For example, GIS-based groundwater vulnerability mapping can help identify areas at higher risk of contamination from agricultural runoff, industrial discharge, or leaching from waste disposal sites [31]. Moreover, GIS can be used to create predictive models for groundwater quality, incorporating both current water quality data and future environmental changes. These models are useful for predicting how factors like climate change, urbanization, and changes in land use might affect groundwater resources. For instance, a study by [34] used GIS to predict future groundwater contamination levels in an agricultural region, considering variables such as fertilizer use and rainfall patterns.

Recent advancements in GIS technology, combined with remote sensing data, have enhanced the accuracy and precision of groundwater quality assessments. Remote sensing data from satellites or drones can provide up-to-date information on land use changes, surface water bodies, and vegetation cover, which are crucial indicators of potential groundwater contamination [13]. These data sets can be integrated into GIS platforms to monitor environmental changes in real-time, allowing for the early detection of potential threats to groundwater quality.

Furthermore, GIS can be used to inform policymakers and stakeholders by creating visual representations of groundwater quality data that are easy to understand. This improves the decision-making process regarding where to allocate resources for water quality monitoring, pollution control, and the development of sustainable water management practices [6].

In this study, GIS will be utilized to develop groundwater quality maps for Osun State Polytechnic, Iree. These maps will help identify contamination sources, visualize spatial variations in water quality parameters (e.g., pH, turbidity, and heavy metal concentrations), and support decision-making to improve water resource management at the institution.

II.STUDY AREA

Osun State Polytechnic, Iree, located in Iree town in Boripe Local Government Area of Osun State, is situated in a region characterized by moderate rainfall and groundwater reliance. Iree (also Ire or Iree Alalubosa) is a Yoruba town in the north-eastern part of Osun State, Nigeria, West Africa. Its geographical coordinates are 7.55 North and East. Iree is one of the major towns in the Boripe Local Government Area of Osun State. It is located on the Osogbo-Ila-Orangun road, about 30 km from Osogbo and 8 kilometers from Ikirun. The institution primarily sources its water from hand-dug wells and boreholes. The study area's geology consists predominantly of Precambrian basement rocks, which can influence groundwater availability and quality [11]. The map of Iree is as shown in Fig. 1.

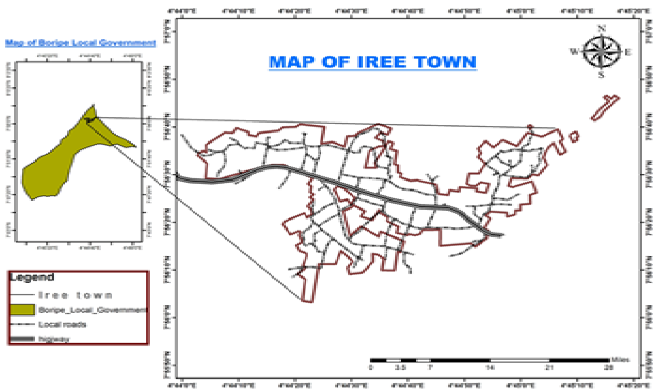

Fig.1 Map of the study area, Osun State Polytechnic, Iree

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International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 9, September 2024

III.METHODOLOGY

Water samples were collected from six hand-dug wells and boreholes across the polytechnic campus. The samples were analyzed for physical (temperature, turbidity, pH), chemical (nitrates, phosphates) following standard laboratory procedures [4] at Obafemi Awolowo University, Ile-Ife (OAU) Central Laboratory. Additionally, GIS was employed to map the sampling locations using Geographic Positioning System (GPS) data. These coordinates were processed in GIS software to analyze spatial relationships and topography

IV.DISCUSSION

TABLE I. RESULTS OF THE PHYSICO-CHEMICAL CHARACTERISTICS OF THE WATER SAMPLES

S/N	Parameter	Unit	SLT Well	Bursary Borehole	Medical Well	Management Borehole	Library Borehole	Art/Design Borehole	Welding/ Fabrication Well	WHO Permissible Limit
1	Water Temperature	(^{0}C)	29.5	29.8	29.4	29.2	29.7	29.3	29.7	25.50^{0}c
2	Colour	(Pt-Co)	3.0	2.0	4.0	3.0	3.0	3.0	4.0	5.0
3	Turbidity	(NTU)	8.0	9.0	7.0	8.0	10.0	8.0	7.0	5.0
4	pH		6.39	5.76	6.05	7.17	5.69	6.75	5.91	7.0
5	Conductivity	(μScm^{-1})	120.3	90.8	91.3	175.2	69.2	159.3	74.4	250Ns/cm
6	Total Dissolved Solids (TDS)	(mg/L)	80.0	60.8	60.0	116.7	46.3	106.2	49.2	300
7	Chloride (Cl^-)	(mg/L)	34.0	26.0	24.0	64.0	20.0	54.0	22.0	250
8	Nitrate (NO_3^-)	(mg/L)	0.038	0.262	0.020	0.023	0.035	0.020	0.069	10
9	Nitrite (NO_2^-)	(mg/L)	0.023	0.157	0.012	0.014	0.021	0.011	0.041	1.0
10	Ammonia (NH_3)	(mg/L)	0.009	0.066	0.005	0.006	0.009	0.007	0.017	
11	Phosphate (PO_4^{3-})	(mg/L)	0.774	0.747	0.737	0.734	0.737	0.731	0.732	0.1

Table 1 shows the results of the physico-chemical characteristics of the water samples. The results show that the water temperatures across the different wells and boreholes range from 29.2°C to 29.8°C. These temperatures are typical for groundwater in tropical climates, where groundwater is usually stable and less influenced by seasonal changes compared to surface water [10]. Such temperatures can influence the solubility of gases and the rates of chemical reactions in the water [14].

The colour values, measured in Pt-Co units, range from 2.0 to 4.0. Colour is an important indicator of water quality, often associated with the presence of organic matter, minerals, or sediments [4]. Lower values indicate clearer water, suggesting minimal organic contamination or sediment load. Slight variations in colour among the samples may be due to different land use or geological conditions affecting the water sources [26] while turbidity values range from 7.0 NTU to 10.0 NTU. Turbidity reflects the cloudiness of water caused by suspended particles and can affect water quality by reducing light penetration and fostering microbial growth [22]. The higher turbidity levels in some samples could be indicative of nearby soil erosion or inadequate filtration processes. Regular monitoring of turbidity is essential as it can impact both the aesthetic quality and the safety of drinking water.

The pH values range from 5.69 to 7.17. pH is a crucial parameter as it affects the solubility and mobility of various contaminants and nutrients in water [8]. The slightly acidic to neutral pH values observed are typical for groundwater in many regions. Lower pH values, such as those at the Bursary Borehole (5.76), may indicate the influence of acidic pollutants or natural soil conditions, while higher values suggest a more neutral environment (Hounslow, 1995). Conductivity values range from 69.2 µS/cm to 175.2 µS/cm. Conductivity measures the ability of water to conduct electrical current, which correlates with the concentration of dissolved ions [32]. Higher conductivity values, such as at the Management Borehole (175.2 µS/cm), may indicate higher concentrations of dissolved salts or minerals, possibly due to contamination or natural geological conditions [5]. Lower values at other sites suggest cleaner water with fewer dissolved substances while the TDS levels range from 46.3 mg/L to 116.7 mg/L. TDS represents the total concentration of dissolved solids in water, influencing its taste, hardness, and potential for scaling [37]. Higher TDS levels, observed at the Management Borehole (116.7 mg/L), could indicate significant mineral content or contamination. Consistently high TDS levels may affect water quality and health [25].

Chloride(Cl-) concentrations range from 20.0 mg/L to 64.0 mg/L. Chloride is a common ion in groundwater, and elevated levels can suggest contamination from sewage or saltwater intrusion [19]. Higher chloride levels at the Management Borehole (64.0 mg/L) might indicate such influences, while lower levels, like those at the Library Borehole (20.0 mg/L), suggest less impact from these sources. The Nitrate levels range from 0.020 mg/L to 0.262 mg/L. Nitrate is a key indicator of agricultural runoff or wastewater contamination [20]. The highest nitrate concentration at the Bursary Borehole (0.262 mg/L) could be related to nearby agricultural activities or improper waste disposal. Lower values elsewhere suggest

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less agricultural impact or better waste management (Sinha et al., 2020).

Nitrite concentrations range from 0.011 mg/L to 0.157 mg/L. Nitrite is often an indicator of recent contamination or incomplete nitrification processes [16]. Higher nitrite levels, such as at the Bursary Borehole (0.157 mg/L), may suggest recent contamination. Consistently low levels at other sites are preferable for safe drinking water [21].

Ammonia levels range from 0.005 mg/L to 0.066 mg/L. Ammonia can indicate contamination from organic waste or sewage and can be toxic at higher concentrations [41]. The higher concentration at the Bursary Borehole (0.066 mg/L) could suggest recent contamination or inadequate treatment. Lower values at other sites indicate better water quality [18].

Phosphate (PO43-) concentrations range from 0.731 mg/L to 0.774 mg/L. Phosphates can originate from agricultural runoff, detergents, or wastewater and contribute to eutrophication [7]. The relatively consistent phosphate levels suggest similar influences across the sites, although elevated levels can lead to ecological imbalances in aquatic environments [35].

Fig. 2 shows the GIS map of the Study area; Osun State Polytechnic, Iree. The GIS mapping provided a visual representation of contamination hotspots, with wells closer to septic tanks showing higher levels of contaminants. Fig. 3 gives the visual description of the study area showing samples wells while Fig. 4. Shows the map of the sampled wells and locations septic tanks. This correlation underscores the need for better spatial planning and groundwater protection measures, such as maintaining safe distances between water sources and potential contamination sites [17]. The results suggest that certain groundwater sources at Osun State Polytechnic, Iree, are unsuitable for direct consumption without treatment, primarily due to chemical imbalances.

GIS analysis helped identify high-risk areas, providing a framework for targeted remediation. Recommendations include relocating wells away from septic tanks, constructing deeper boreholes, and implementing regular water quality monitoring [9]; [27]. Establishing a public water treatment facility is also advised to ensure consistent access to safe drinking waters.

Fig. 2. Map of the Study area, Osun State Polytechnic, Iree

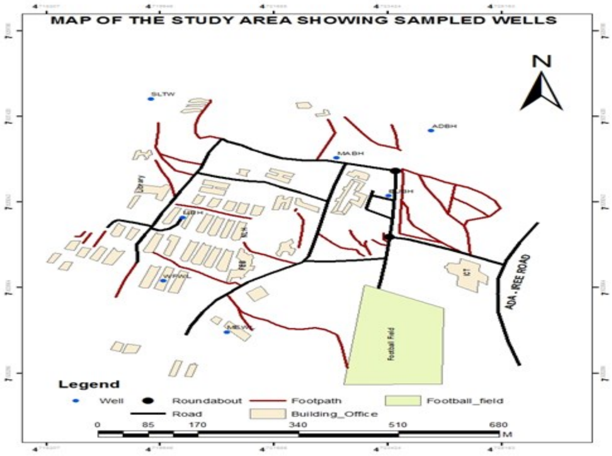

Fig. 3. Map of the study area showing samples wells

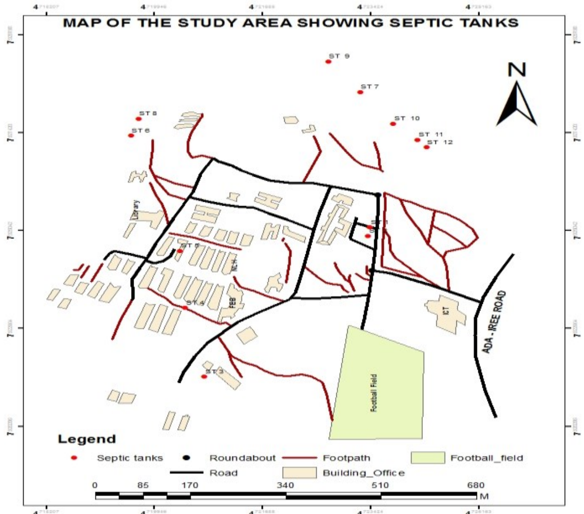

Fig. 4. Map of study area showing locations septic tanks

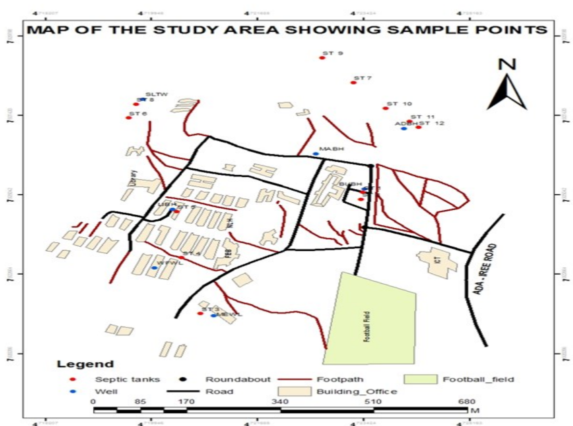

Fig. 5. Map of the sampled wells and locations septic tanks

V.CONCLUSION

This study highlights the importance of integrating GIS in groundwater quality assessment, providing critical insights into the spatial distribution of contamination risks at Osun State Polytechnic, Iree. Through comprehensive analysis of physical, and chemical, the study identifies key contamination sources and suggests actionable steps to improve groundwater management. The findings emphasize the need for sustainable water practices and ongoing monitoring to safeguard public health and ensure the long-term viability of groundwater resources. Further study is recommended for the bacteriological analysis of the sampled wells to determine the effects of the septic tanks location on the sampled wells

ACKNOWLEDGMENT

The success of this research would not have been possible without the invaluable contributions of various individuals and organizations. We would like to express our deepest gratitude to Mr. Femi-Fadeyi and Mr. Taiwo Akintayo both of the Department of Civil Engineering, Federal Polytechnic, Ile-Oluji for their unwavering support, and insightful suggestions throughout the course of this study. Their expertise and commitment significantly enriched the quality of this work.

We are also deeply grateful to Obafemi Awolowo University, Ile-Ife (OAU) Central Laboratory for providing the necessary resources and a conducive environment that made this research possible. The access to facilities was instrumental in completing this project.

Thank you all for your generous support.

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