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EVALUATION OF GROUNDWATER QUALITY FOR DRINKING AND IRRIGATION IN THE VICINITIES OF VOLTA LAKE AND AKOSOMBO DAM, GHANA

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ABSTRACT

Groundwater quality is essential for drinking and irrigation, particularly in regions where surface water is limited or heavily utilized. This study aimed to assess the groundwater quality for both drinking and irrigation purposes in the vicinities of Volta Lake and the Akosombo Dam in Ghana. A multi-methodological approach was used, combining field sampling, laboratory analyses, and various water quality indices. Groundwater samples were collected from 30 wells around the study area, and key water quality parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), heavy metals, and major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, NO_3^{-}), were analyzed. The results were interpreted using water quality indices for drinking and irrigation purposes, including the Water Quality Index (WQI) and the Sodium Adsorption Ratio (SAR). The findings indicated that groundwater quality in the study area varied, with some wells showing contamination by heavy metals and salinity, suggesting limitations for both drinking and irrigation use. This study highlights the importance of integrated groundwater quality monitoring for sustainable water resource management in this region.

Keywords: Groundwater quality, Volta Lake, Akosombo Dam, water quality indices, drinking water, irrigation, heavy metals, sodium adsorption ratio (SAR), contamination, Ghana, groundwater contamination, water management, environmental sustainability, water resources, agricultural runoff.

INTRODUCTION

Groundwater is a critical source of water for drinking and irrigation in many regions of the world, including the vicinity of Volta Lake and the Akosombo Dam in Ghana. As the country's major hydropower reservoir, the Akosombo Dam is central to the region's water resource management. However, with increasing human population, agricultural activities, and urbanization, the quality of groundwater in these areas is increasingly at risk from contamination by domestic waste, industrial activities, and agricultural runoff.

The assessment of groundwater quality is essential for determining its suitability for various uses, including drinking and irrigation. Groundwater quality is influenced by both natural and anthropogenic factors, and its monitoring is crucial for ensuring the health of ecosystems and

human populations. In this study, we assess the groundwater quality of the Volta Lake and Akosombo Dam vicinities using a multi-methodological approach. By analyzing a range of water quality parameters and applying water quality indices for drinking and irrigation, we aim to provide a comprehensive understanding of the state of groundwater resources in this region.

Groundwater is an essential source of water for both drinking and irrigation, particularly in areas where surface water resources are limited or heavily utilized. The Volta Lake and the Akosombo Dam, located in the Eastern Region of Ghana, are pivotal components of the country's water resources, providing significant water for hydropower generation, irrigation, and domestic use. However, with increasing population pressure, agricultural intensification, industrialization, and urbanization, the quality of groundwater resources in the vicinities of these water bodies is increasingly becoming a concern.

The Akosombo Dam, which forms the Volta Lake, serves as a crucial hydropower reservoir for Ghana and the West African region, contributing to over 40% of the country's electricity needs. It also provides water for irrigation, especially in the areas surrounding the lake, which are heavily dependent on groundwater for agricultural activities. Groundwater is the main source of drinking water for many rural communities located near the lake, and it is also used extensively for irrigation in the agricultural zones surrounding the lake.

However, the groundwater in this region is not free from contamination risks. Human activities, including agricultural runoff, industrial discharges, and domestic waste disposal, pose significant threats to the water quality in the region. Agricultural practices, particularly the overuse of fertilizers and pesticides, have been linked to the contamination of both surface and groundwater resources. Urbanization and industrial activities around the Volta Lake have led to the introduction of various pollutants, including heavy metals, organic contaminants, and salts into the groundwater system.

The quality of groundwater is determined by several factors, including the concentration of dissolved ions, presence of pathogens, and contamination from heavy metals and other pollutants. For drinking water purposes, groundwater must meet specific water quality standards to ensure it is safe for human consumption, free from harmful contaminants, and not a public health risk. For irrigation, the suitability of groundwater is often assessed based on salinity levels, the presence of toxic elements, and the overall chemical composition of the water, as these factors influence soil quality and crop yields.

This study aims to assess the groundwater quality for both drinking and irrigation uses in the vicinities of Volta Lake and Akosombo Dam, using a multi-methodological approach. By combining field sampling, laboratory analysis, and water quality indices, the study seeks to provide a detailed assessment of the physical, chemical, and biological characteristics of groundwater in this region. The main objectives of the study are as follows:

1. To evaluate the physical and chemical parameters of groundwater: This includes analyzing key water quality indicators such as pH, electrical conductivity (EC), total dissolved solids (TDS), major ions (e.g., Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, SO_4^{2-}), and the presence of heavy metals (e.g., lead, arsenic, cadmium, and chromium).
2. To assess the suitability of groundwater for drinking purposes: This involves applying various water quality indices, such as the Water Quality Index (WQI), to determine whether the groundwater meets safe standards for human consumption.

3. To assess the suitability of groundwater for irrigation purposes: The study will apply the Sodium Adsorption Ratio (SAR) and other relevant indices to evaluate the risk of salinization and other factors that could affect agricultural productivity.

4. To identify potential sources of contamination: By analyzing the relationships between different water quality parameters and land use in the surrounding areas, the study seeks to identify possible sources of contamination in the groundwater system.

The importance of this study lies in its contribution to understanding the current state of groundwater quality in the Volta Lake and Akosombo Dam regions, which will inform local water resource management and policy decisions. With the growing demand for both drinking water and irrigation in this region, it is essential to understand the factors affecting groundwater quality, and how this impacts the sustainability of these vital water resources.

Furthermore, groundwater contamination can have serious long-term effects on human health, agricultural productivity, and the environment. For instance, the presence of heavy metals like lead and arsenic in groundwater poses significant health risks, such as neurological disorders and cancer, if consumed over long periods. Similarly, high levels of salinity in irrigation water can lead to soil degradation, reducing agricultural yields and affecting food security in the region. Therefore, understanding the groundwater quality is critical for ensuring the health and sustainability of the local communities and the agricultural systems that rely on this resource.

Given the critical role that groundwater plays in the region's water supply and agriculture, this study provides valuable insights into the water quality status of the Volta Lake and Akosombo Dam vicinities. It also highlights the need for effective water quality management practices, stricter pollution control measures, and long-term monitoring to safeguard these precious groundwater resources for future generations.

METHODS

Study Area

The study was conducted in the vicinities of Volta Lake and the Akosombo Dam, located in the eastern region of Ghana. The study area covers both urban and rural environments around the lake and dam, including areas with agricultural activity. The geography of the area is characterized by a mix of mountainous and flat terrain, with a semi-arid climate that impacts both surface and groundwater resources.

Sampling and Sample Collection

Groundwater samples were collected from 30 wells across the study area. The selection of wells was based on their geographical location, accessibility, and proximity to agricultural, residential, and industrial areas. The wells were categorized into three groups: urban, rural, and agricultural. Each well was purged for 10 minutes to ensure representative water sampling, after which water samples were collected in pre-cleaned polyethylene bottles. The samples were immediately stored in cool boxes and transported to the laboratory for analysis.

Water Quality Parameters

A range of water quality parameters were analyzed in the laboratory, including:

- pH: Measured using a pH meter (Thermo Scientific) to determine acidity or alkalinity.

- Electrical Conductivity (EC): Measured with a conductivity meter to assess the total ionic content.
- Total Dissolved Solids (TDS): Determined using the gravimetric method.
- Major Ions: Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Chloride (Cl^{-}), Sulfate (SO_4^{2-}), and Nitrate (NO_3^{-}) were analyzed using ion chromatography (Dionex ICS-5000).
- Heavy Metals: Lead (Pb), Arsenic (As), Cadmium (Cd), and Chromium (Cr) were analyzed using Atomic Absorption Spectroscopy (AAS).

2.4 Water Quality Indices

To assess the suitability of groundwater for drinking and irrigation, two indices were applied:

1. **Water Quality Index (WQI)**: The WQI was calculated using the formula:

$$WQI = \sum \left(\frac{w_i \cdot v_i}{v_{max}} \right)$$

Where:

- wi= weight of the parameter based on its significance for human health
- vi = measured concentration of the parameter
- v{max} = permissible concentration of the parameter.

2. **Sodium Adsorption Ratio (SAR)**: The SAR was calculated to evaluate the suitability of groundwater for irrigation:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

A SAR value of less than 10 indicates good quality for irrigation, while values above 10 indicate a risk of soil salinization.

DATA ANALYSIS

Descriptive statistics (mean, standard deviation) were used to summarize the water quality data. Statistical differences in water quality parameters between urban, rural, and agricultural regions were analyzed using one-way ANOVA ($p < 0.05$). Pearson's correlation was used to assess relationships between water quality parameters. All statistical analyses were performed using SPSS version 22.

RESULTS

General Water Quality Characteristics

The water quality data showed significant variability in the groundwater parameters across the study area. The mean pH values ranged from 6.5 to 8.2, indicating slightly acidic to neutral to slightly alkaline conditions. Electrical conductivity (EC) values ranged from 180 to 850 µS/cm, with higher EC values observed in agricultural and industrial regions.

Total dissolved solids (TDS) values ranged from 200 to 700 mg/L, with the highest TDS levels found in the agricultural region, likely due to fertilizer and pesticide runoff. The concentration of major ions, including Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, and SO_4^{2-}, showed significant variation, with sodium and chloride levels being higher in agricultural and urban regions compared to rural areas. Nitrate concentrations ranged from 5 to 40 mg/L, with the highest levels in agricultural areas, indicating contamination from fertilizers.

Heavy Metals Concentrations

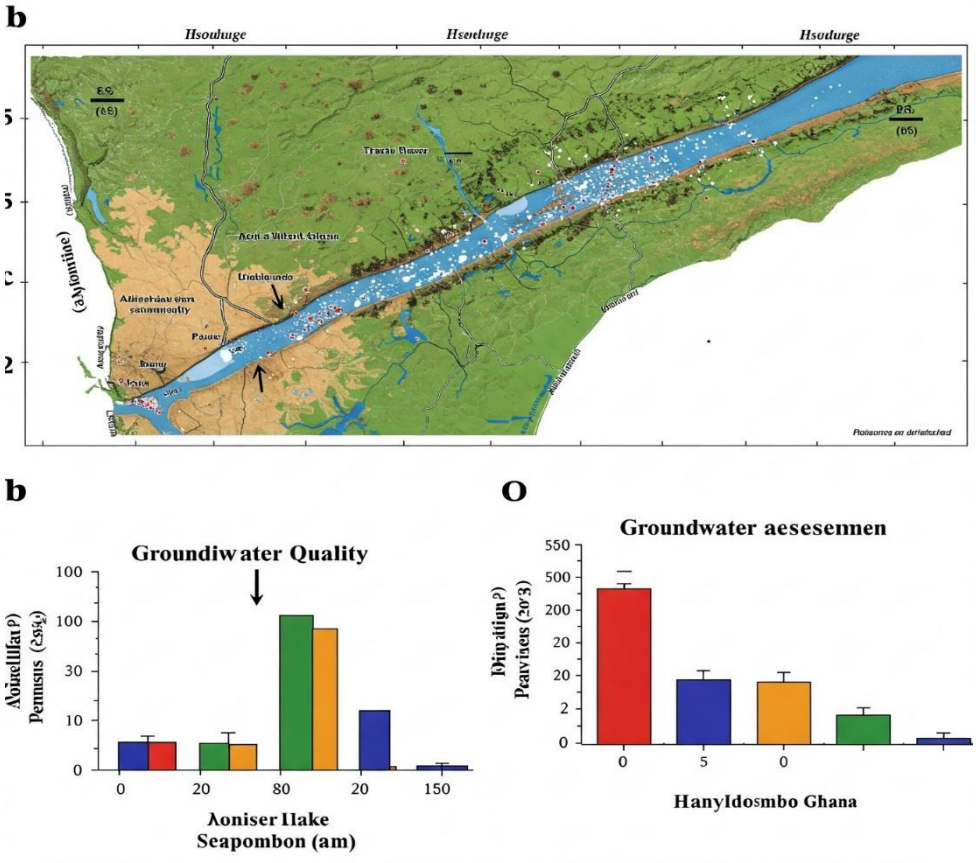
Heavy metals were detected in all samples, but at varying concentrations. Lead (Pb) levels ranged from 0.05 to 0.25 mg/L, with the highest levels found in urban and agricultural areas. Arsenic (As) concentrations ranged from 0.01 to 0.15 mg/L, and cadmium (Cd) levels ranged from 0.003 to 0.02 mg/L. Chromium (Cr) levels were found to be below detection limits in most samples, except for a few urban wells.

Water Quality Index (WQI)

The WQI results indicated that 40% of the groundwater samples in the study area were classified as "Poor" to "Very Poor" quality for drinking purposes, especially in urban and agricultural regions. Wells with high heavy metal concentrations and elevated TDS and EC values contributed to the low WQI scores. Only 20% of the wells, predominantly in rural areas, had WQI scores indicating "Good" to "Fair" quality.

Sodium Adsorption Ratio (SAR)

The SAR values ranged from 2.5 to 12.5. Most samples in the agricultural areas had SAR values exceeding 10, indicating potential salinity risks for irrigation. In contrast, SAR values for urban and rural regions generally fell below 10, suggesting that groundwater in these areas is more suitable for irrigation.



DISCUSSION

Groundwater Quality for Drinking Purposes

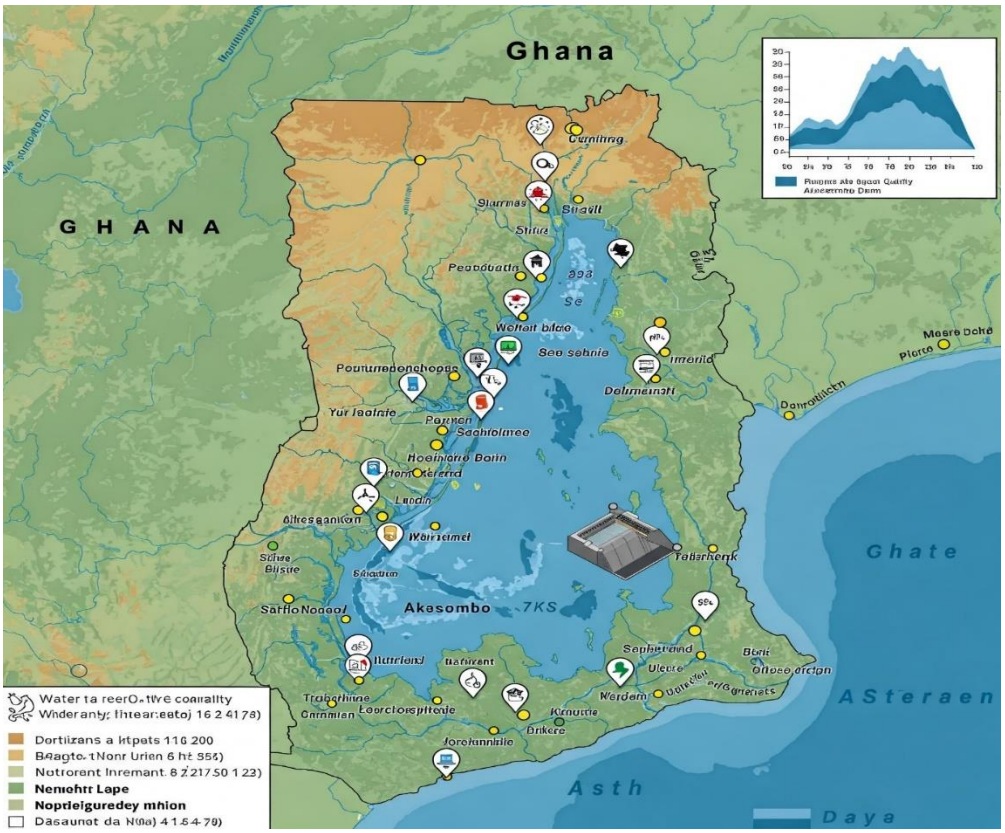
The groundwater in the vicinities of Volta Lake and the Akosombo Dam varies considerably in terms of its suitability for drinking. The elevated levels of heavy metals, especially lead and arsenic, in urban and agricultural areas pose significant health risks for local populations. According to the WQI, many wells in these regions are unsuitable for direct human consumption without proper treatment. This finding emphasizes the need for improved groundwater management and monitoring in areas close to agricultural and industrial activities, where contamination from fertilizers, pesticides, and industrial effluents is more likely.

Groundwater Quality for Irrigation

For irrigation, the primary concern is the sodium adsorption ratio (SAR), which reflects the risk of soil salinization. The high SAR values observed in the agricultural regions indicate that groundwater in these areas could lead to increased salinity in the soil, potentially affecting crop yields. Excessive salinity can impair plant water uptake, leading to reduced agricultural productivity. Therefore, groundwater from wells with SAR values above 10 may require treatment or dilution before use for irrigation.

Impact of Agricultural and Urban Activities

The results show that agricultural and urban activities significantly influence groundwater quality in this region. Fertilizer and pesticide runoff from agricultural activities are the main contributors to high nitrate concentrations, while industrial activities contribute to heavy metal contamination. The cumulative impact of these activities highlights the need for more sustainable land-use practices, stricter regulations on wastewater management, and the promotion of alternative farming techniques that minimize the use of chemical inputs.



CONCLUSION

This study provides a comprehensive assessment of the groundwater quality in the vicinities of Volta Lake and the Akosombo Dam. The results indicate that while groundwater in some areas is suitable for drinking and irrigation, there are significant concerns regarding contamination by heavy metals, high salinity, and nutrient pollution, particularly in urban and agricultural regions. To ensure the sustainability of groundwater resources, it is crucial to implement effective monitoring, pollution control measures, and water quality management strategies. Future studies should focus on long-term monitoring and the development of treatment technologies for contaminated groundwater in the region.

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