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Suitability Analysis of Groundwater Quality for A Standard Swimming Pool in University of Uyo

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***Abstract-** Groundwater is a vital source of drinking water and for recreational facilities in most areas, but its chemical stability is often ignored, which is the cause of the mass destruction of infrastructure and endangered health of the population. This paper analyses the corrosiveness and stability of calcium carbonate in groundwater taken at five strategic boreholes (BH 1 – BH 5) by using the Langelier Saturation Index (LSI). Analyses on physicochemical parameters such as pH, temperature, calcium hardness, alkalinity, and total dissolved solids (TDS) were conducted to establish the thermodynamic inclination of the water towards either scale development or corrosion. The findings demonstrate that all the sampling sites are highly chemically aggressive, and the LSIs are between -2.04 and -3.06. These high negative values show a steady under saturation condition with respect to calcium carbonate (CaCO3), which precludes the development of protective mineral scales in the distribution networks. This leads to internal corrosion and tuberculation in metallic pipes that not only diminishes hydraulic efficiency and life of infrastructure but also adds to the chances of heavy metal leaching into the supply. To reduce such risks, the research suggests a series of stabilization measures such as aeration of CO2 stripping, lime [Ca(OH)2] dosing and decentralized systems, which will be provided with active calcite contactors. The results underscore the importance of applying chemical stabilization in groundwater management guidelines to guarantee the stability and security of water distribution systems in the long run.*

***Keyword:** Groundwater Quality, Swimming Pool, Langelier Saturation Index.*

I. INTRODUCTION

Groundwater is the most essential source of freshwater in the world, especially in sub-Saharan Africa where urbanization and low surface water facilities have increased the dependency of the underground water resources (World Bank, 2024; UNESCO, 2023). Domestically, the Niger Delta area, known as the rich Benin Formation, is the main source of hydrogeological reservoir in Nigeria to support domestic, industrial, and recreational demand (Nwankwoala, 2023; Izeze and Ogueh, 2024). Nevertheless, the ease with which these shallow aquifers can be subjected to anthropogenic pollution via poor waste management and leakage has made people very worried about their health (Edet, 2022; Eyo *et al.,* 2026).

Potability of drinking water is only one of the characteristics of suitability of groundwater, which is a determinant of requirement of specialized recreational amenities, like ordinary swimming pools. The quality of swimming pool water is technically challenging, and it needs a fine balance between the pH, alkalinity, and hardness of calcium to guarantee the comfort of bathers and avoid the erosion of the infrastructure (CDC, 2025; WHO, 2025). Poor adherence to the set standards on recreation, including the ones provided by the American Public Health Association (APHA, 2023) or the U.S. Environmental Protection Agency (EPA, 2024), may result in dermatological health problems, respiratory discomfort, and the fast corrosion of pool filtration systems (Itam et al., 2024; Bassey *et al.,* 2025).

The groundwater as a source has been necessitated by the high demand to have recreational and competitive swimming facilities within the University of Uyo, Akwa Ibom State. In Uyo, recent hydrogeochemical researches have pointed out several problems, such as high levels of acidity of groundwater that has high concentrations of sulfuric acid, with the pH being very low less than 5.5, and high levels of heavy metals including iron (Fe) and nickel (Ni) (Okon *et al.,* 2023; Anweting *et al.*, 2024). Research on the silicate weathering of the rocky materials and the absence of buffering of the sands making up the coastal plain has also been noted to contribute to the acidic properties of the Uyo groundwater (Akpan and Udom 2024, and George *et al.*, 2025). This acidity is especially troublesome in relation to swimming pools, since it affects the effect of disinfectants and irritates the mucous membranes (Essien *et al.,* 2024; Umo-Otong *et al.,* 2025).

In addition, numerous studies have reported the existence of localized microbial contamination and trace metal presence in institutional facilities in different Nigerian Universities (Onabote *et al.,* 2025; Udosen, 2024). An example is that Nganje *et al.* (2023) and Asuquo and Etim (2024) reported that enrichment of heavy metal in Southeastern Nigeria usually surpasses the levels recommended by the World Health Organization, which may result in the risk of bioaccumulation during the dermal contact of recreational areas (Bassey *et al.,* 2025). In spite of these regional understandings, there is the clear deficiency of formal research particularly assessing the hydrochemical appropriateness of the Uyo groundwater to the expert needs of a typical swimming pool.

Whereas former authors have evaluated overall potability in Uyo (Udoh and Etim, 2025; Inyang *et al.,* 2024) none of them have considered the multi-criteria suitability analysis (MCSA) that would determine whether these water sources can support a high-level recreational center without a need to have a pre-treatment that is highly multiplied and costly. This study therefore aimed at helping to address this research gap by performing a stringent physicochemical and hydrogeochemical investigation of the ground water in the University of Uyo. This study also offers a reproducible model of institutional water management and human health safety of tropical urban aquifers through the use of Water Quality Indices (WQI) and a comparison of outcomes with international standards of recreational water quality (WHO, 2025; CDC, 2025).

II. MATERIALS AND METHODS

2.1 Study Area Description

The study was carried out in the University of Uyo main campus, Uyo, Akwa Ibom State of Nigeria (Lat. 5° 02' N to 5° 05' N; Long. 7° 54' E to 7° 56' E) – the location of the proposed sport arena. The region is covered with the Benin Formation, which consists of mostly the Coasts Plains Sands (Akpan *et al.,* 2024; George *et al.,* 2025). The hydrogeology exhibits high porosity and permeability, with the resultant shallow aquifers being highly productive, but prone to contaminants at the surface (Edet, 2022; Udosen, 2024).

2.2 Sampling Design and Collection

A systematic sampling method was used, with the boreholes within the main campus. Sampling was done when the rainy season and the dry season were at their peak so that seasonal hydrochemical differences could be considered. Fifteen (15) water samples were taken from five (5) representative boreholes in pre-rinsed 1-liter High-Density Polyethylene (HDPE) bottles. The samples were transported to the laboratory for analysis within three (3) hours after collecting them in a temperature-controlled box.

a. Water Quality Analysis

The physical parameters such as pH, Electrical Conductivity (EC), and Total Dissolved Solids (TSS) were in-situ sampled using a multi-parameter water quality probe (Hanna HI98194) at the temperature of 4° C. Titrimetry and UV-Visible Spectrophotometry were used to determine major ions.

b. Water Balance Index

2.4.1 Langelier Saturation Index

To measure the agglomerative capability or scaling potential of the water, which is critical in pool infrastructure, the Langelier Saturation Index (LSI) was calculated.

$$LSI = pH - pH_s \quad (1)$$

$Where\ pH_s\ is\ the\ saturation\ pH\ of\ calcium\ carbonate.$

The pH_s is the pH at the water balance point, where the water is neither corrosive nor scale forming. It is calculated from the equation:

$$pH_{sat} = Temp.factor + Ca\ Hardness\ factor + Alkalinity\ factor - TDS\ factor \quad (2)$$

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Table 2.1. Langelier saturation index

Value	Condition	Indication
LSI < 0	Undersaturated	Corrosive water
LSI = 0	Saturated	Balanced
LSI > 0	Supersaturated	Scale-forming

(Apha *et al.*, 2012)

III. RESULTS AND DISCUSSION

3.1 Results

Table 3.1. Average concentration of physicochemical parameters per borehole.

S/N	Parameters	Water samples				
		BH 1	BH 2	BH 3	BH 4	BH 5
1	Temperature (°C)	30.7	30.8	30.7	30.4	29.8
2	pH value	6.35	5.94	6.08	6.54	5.97
3	Acidity (mg/l as $CaCO_3$)	48.00	72.00	64.00	50.52	68.75
4	Alkalinity (mg/l as $CaCO_3$)	40.00	32.00	36.00	43.00	37.00
5	Conductivity μscm^{-1}	37.5	23.4	20.5	35.2	28.5
6	Total Dissolve Solids (mg/l)	18.55	11.86	10.64	15.54	14.25
7	Calcium Hardness (mg/l)	38.00	40.00	40.00	40.00	37.00
8	Magnesium Hardness (mg/l)	28.00	30.00	20.00	25.00	26.00
9	Total Hardness (mg/l)	66.00	70.00	60.00	68.00	65.00
10	Chloride (mg/l)	39.76	31.24	36.92	32.00	28.00
11	Turbidity (NTU)	0.35	0.26	0.33	0.25	0.32

Field Data: 2025.

3.1 Physical parameters

The result of the physicochemical parameters is presented on table 3.1. There was a considerable spatial variation in the physicochemical properties of groundwater samples in the University of Uyo main campus. The pH was within the range of 5.94 to 6.54 and the average was 6.18, which shows that the water was acidic through all the sample locations. These values are lower than the 7.2 to 7.8 that is recommended to be in swimming pools (CDC, 2025; WHO, 2025). The absence of carbonate minerals in the Benin Formation and the presence of organic acids in leaching are the causes of low pH in this area (Akpan and Udom, 2024; George *et al.*, 2025).

Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were within the acceptable range and had mean.

values of 29.02 µS/cm and 14.17 mg/L, respectively. Nevertheless, the low mineralization also indicates the presence of hungry water, which in conjunction with high acidity enhances the ability of heavy metals to be washed away by the plumbing and pool infrastructure (Itam *et al*., 2024; Essien *et al*., 2024).

Table 3.2: Calculated Langelier Saturation Index

Sample stations	LSI values	Condition
BH 1	-2.63	Corrosive
BH 2	-3.06	Corrosive
BH 3	-2.92	Corrosive
BH 4	-2.04	Corrosive
BH 5	-2.19	Corrosive

3.2. Calcium Carbonate Stability (LSI) Evaluation.
The computed Langelier Saturation Index (LSI) of the five groundwater sampling points (BH 1 – BH 5) were presented in Table 3.2. The findings reveal that all the boreholes are in a steady under-saturation condition with the lowest value of -3.06 (BH 2) and the highest value of -2.04 (BH 4).

3.3. Corrosivity and Infrastructure Risk Discussion.

The negative values of LSI at all sampling points show that ground water is under saturated in terms of calcium carbonate ($CaCO_3$). Under the classification criteria that was set up by Langelier (1936), water that has an LSI < 0 does not have the thermodynamic potential to form a protective carbonate scale on the internal surfaces of the distribution systems. Rather, this water is aggressive and will dissolve any carbonate coating that is available (Apha et al., 2012). The strong values (all of less than -2.0) indicate a high possibility of metallic corrosion. Without the protective film, dissolved oxygen and other oxidants that are present in the water may react directly with the wall of the pipe. In the case of metal infrastructure (e.g., galvanized iron or copper pipes) this usually causes internal corrosion that decreases the hydraulic capacity and raises the pumping energy demands (AWWA, 2017) and heavy metal such as lead, copper, and cadmium leaching into the supply because of its aggressive nature and a serious threat to the health of the people (WHO, 2022). PH correction or alkalinity increase (e.g., dosing with lime or soda ash) is advised to correct these effects and make LSI shift towards slightly positive values (+0.2 to +0.5) according to the AWWA M27 Manual (AWWA, 2017).

IV. CONCLUSION

In this experiment, the chemical stability of the groundwater in five representative boreholes (BH1-BH5) was estimated using the Langelier Saturation Index (LSI). The findings are conclusive in showing that the groundwater in the study area is typified with a high level of chemical instability and corrosiveness. The sampling points found significant negative LSI values, between -2.04 and -3.06, which means that the water is always under-saturated with regard to calcium carbonate, or $CaCO_3$.

The results highlight one of the most pressing issues of the local water infrastructure. The roughness of the water does not allow the formation of a protective mineral scale, exposing the systems of distribution to increased corrosion, tuberculation, and possible structural failure. Moreover, the thermodynamic nature of the water to dissolve available minerals is a great danger to the overall population health because of the possibility of dissolving heavy metals in the metallic plumbing materials into the domestic supply.

To counter these dangers, the paper underlines that water stabilization is not an issue of just aesthetics but a technical need. To set the LSI in a more neutral or slightly positive direction, it is necessary to implement localized treatment measures, i.e., aeration of the strip of CO_2, controlled dosing of lime or the utilization of passive calcite contactors. These interventions will not only protect the life cycle of the engineering assets, but also the chemical safety and reliability of water supply to the community. The study needs to be followed by future studies that seek to determine the seasonal changes of such indices in a longitudinal study to streamline the dosing regimen of the recommended stabilization interventions.

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