Volume 9, Issue 7, July – 2024 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL877

Determination of Water Quality for Ground Water Near Municipal Dumpsite in Ibadan Southwest Nigeria

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Abstract:- Access to clean drinking water is crucial for human health and survival. In vicinities near municipal dumpsites, ensuring groundwater quality is especially vital to safeguard the ecosystem and human health. This study utilized the Entropy Weighted Water Quality Index (EWQI), a novel assessment tool, to evaluate groundwater near the Awotan dumpsite in southwestern Nigeria. Forty-five groundwater samples were collected during rainy and dry seasons and explored for groundwater quality using EWQI. The physicochemical parameters fall within permissible limits for domestic purposes during both seasons. Nonetheless, 2% of the samples surpassed the recommended nitrate limit of 45 mg/L, and all samples had iron levels above the 0.3 mg/L threshold. The calculated EWQI values for these samples ranged from 20 to 528, with 2% deemed excellent, 16% good, 51% medium, 18% poor and 13% extremely poor in terms of water quality for domestic use. The spatial variability in water quality levels means that there are localised impacts of the dumpsite and thus there is need for targeted management strategies. We recommend the government undertake sustainable retrofitting to enhance landfill design, incorporating an efficient leachate collection system to lessen groundwater pollution. Additionally, nearby residents should implement water treatment methods to improve water quality and minimize health risks.

Keywords:- *Awotan Dumpsite, EWQI, Water Quality, Public Health.*

I. INTRODUCTION

Clean drinking water is crucial for human health, yet municipal dumpsites pose significant risks to groundwater quality worldwide [1]. This issue is particularly pressing in developing countries, where rapid urbanization and inadequate waste management practices exacerbate the risks of groundwater pollution [2]. In Ibadan, Southwest Nigeria, Awotan dumpsite serves as a major waste disposal site, impacting nearby communities with potential groundwater contamination [3]. Despite its essential role, groundwater near dumpsites is vulnerable to pollutants, threatening public health and ecosystem integrity. Previous studies in this area have primarily compared the physicochemical parameters of the groundwater to WHO standards. However, none have utilized the Entropy Water Quality Index (EWQI), which offers a more comprehensive assessment by integrating multiple physicochemical parameters. This novel approach provides a standardized method for evaluating water quality across diverse environmental settings, enhancing comparability and facilitating informed decision-making. This study aims to fill this gap by applying EWQI to assess the hydrogeochemical characteristics of groundwater near Awotan dumpsite, providing a robust evaluation of contamination levels and their implications for human health and environmental sustainability.

II. METHODOLOGY

- *Study Area*:

The study was done in Awotan, which hosts the principal municipal solid waste dumpsite in Ibadan, Oyo State, Nigeria. The Awotan dumpsite (Fig. 1) is positioned in the Ido Local Government Area and serves as a major facility for disposing of municipal solid waste. It spans an area of 20 hectares and receives about 95,775 metric tonnes of waste every year from both authorized and unauthorized sources [4], impacting nearby residential areas through issues like leachate contamination and other environmental risks. The types of waste include domestic, commercial, electronic, medical, and industrial waste [3].

- *Water Sampling and Analysis*:

In February 2022, forty-five groundwater samples were collected from the vicinity of the Awotan dumpsite, and these were resampled in June 2022. The sampling area falls within Longitude 7° 27′ 15″ to 7° 28′ 15″ N and Latitude 3° 50′ 30″ to 3° 51′ 30″ E. Sampling locations (Fig. 2) were recorded using a portable Global Positioning System (GPS, GARMIN GPSMAP 64s). Water samples were collected in high-quality polyethylene bottles of 25 cl and 50 cl capacities for subsequent chemical analysis. These bottles were washed with deionized water and sterilized. At each site, bottles were rinsed 3 to 4 times with the source water before collecting the samples. The 25 cl samples were acidified with two drops of 20% nitric acid for preservation. Each groundwater sample was labelled with a prefix "A" for the 25cl bottles and "B"

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for the 50cl bottles. To ensure sample integrity, low-temperature conditions were maintained for the samples by promptly transporting them to the laboratory. The physical parameters including pH and electrical conductivity (EC), were measured *in situ* using the portable Hanna (HI 9811-5 brand) pH/EC/TDS meter. The analysis of major anions and cations (Na, K, Ca, Mg, Fe, F, Cl, SO_4, HCO_3, and NO_3) followed standard protocols. Anions (F, Cl, SO_4, HCO_3, and NO_3) were analysed using JENWAY Aqua nova spectrophotometer while cations (Na, Ca, Mg, K and Fe) were analysed using an Atomic Absorption Spectrometer (AAS, PerkinElmer 400).

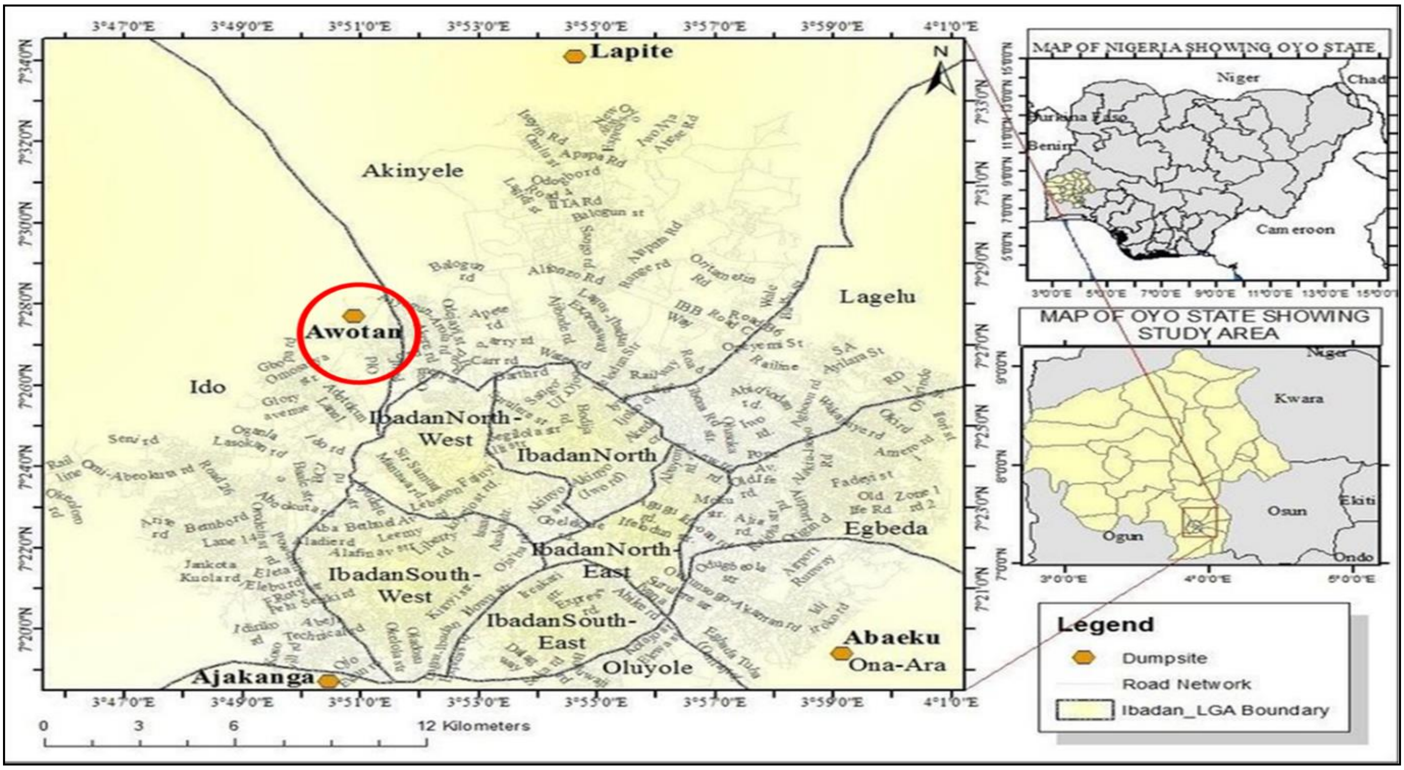

Fig 1 Road Network Map of Ibadan
(Source: Google Map) with Red Ring Showing Awotan Dumpsite.

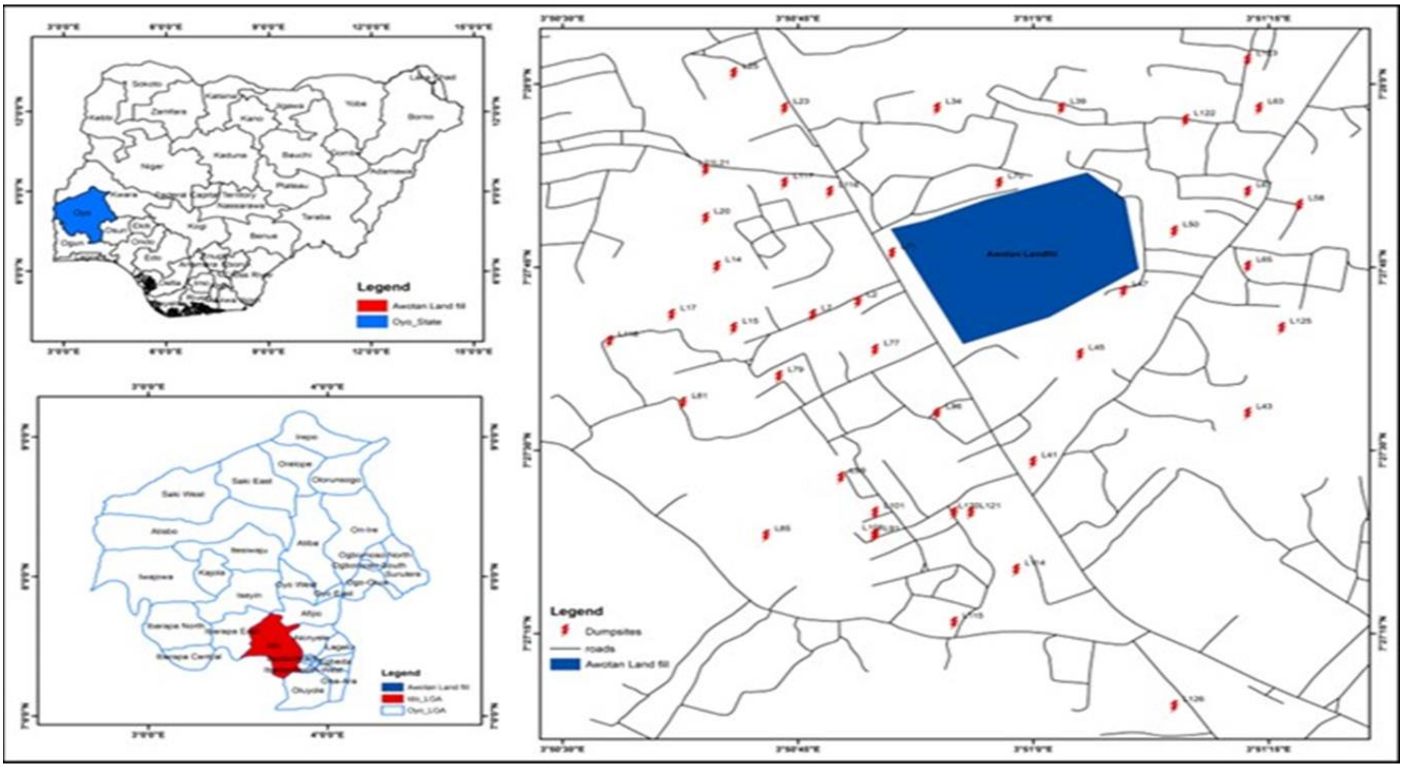

Fig 2 Location Map with Sampling Points

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➢ *Computation of Entropy Water Quality Index (EWQI):*

EWQI is a tool for evaluating the overall quality of groundwater for ingestion purposes [5.6]. This tool is an effective technique that integrates the data of all physicochemical parameters to provide a representative value which reflects the quality of water is suitable for consumption. The steps outlined below, adapted from Gorgij and others [6] detail the algorithms for calculating the EWQI.

➢ *Estimation of Eigenvalue Matrix "X"*

The eigenvalue matrix "X," which incorporates all physicochemical parameters, is calculated using Eq. (1):

$$X = \begin{vmatrix} x_{11} & x_{12} & \dots x_{1n} \\ x_{21} & x_{22} & \dots x_{2n} \\ x_{m1} & x_{m2} & \dots x_{mn} \end{vmatrix} \quad \textbf{Eq. 1}$$

Here, m (i=1,2,3, …, m) denotes each groundwater sample and n (i=1,2,3, …, m) represents the number of physicochemical parameters of each sample

➢ *Estimation of Standardized Matrix "Yij"*

The standardized matrix "Yij" is derived from Eq. (2)

$$Y_{ij} = \frac{x_{ij} - (x_{ij})min}{(x_{ij})max - (x_{ij})min} \quad \textbf{Eq. 2}$$

Where, X_{ij} is the primary matrix; (X_{ij})min and (X_{ij})max are the minimum and maximum values of the physiochemical parameters, respectively.

➢ *Estimation of Standard Assessment Matrix "Y"*

The standard assessment matrix "Y" is determined using Eq. (3):

$$Y = \begin{vmatrix} y_{11} & y_{12} & \dots y_{1n} \\ y_{21} & y_{22} & \dots y_{2n} \\ y_{m1} & y_{m2} & \dots y_{mn} \end{vmatrix} \quad \textbf{Eq. 3}$$

➢ *Computation of the Information Entropy "ej"*

The information entropy "ej" is computed using Eqs. (4) and (5):

$$P_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{m} Y_{ij}} \quad \textbf{Eq. 4}$$

$$e_j = -\frac{1}{lnm} \sum_{i=1}^{m} P_{ij} ln P_{ij} \quad \textbf{Eq. 5}$$

➢ *Computation of Entropy Weight "wj"*

The entropy weight "wj" is calculated using Eq. (6):

$$w_j = \frac{(1-e_j)}{\sum_{j=1}^{n}(1-e_j)} \quad \textbf{Eq. 6}$$

➢ *Calculation of Qualitative Rating Scale "qj" of the "j"*

The qualitative rating scale "q_{j}" for the parameter "j" is determined using Eq. (7):

$$q_j = \frac{C_j}{S_j} \times 100 \quad \textbf{Eq. 7}$$

Where Cj denotes the concentration of the parameter j (mg/L) in each water sample and Sj denotes the drinking water quality standards of Standard Organization of Nigeria [7] or World Health Organization [8] for parameter j (mg/L).

➢ *Final Calculation of EWQI*

The EWQI is computed using Eq. (8):

$$EWQI = \sum_{j=1}^{n} w_j q_j \quad \textbf{Eq. 8}$$

➢ *The Groundwater Quality based on the EWQI is Classified into Five Ranks, as Shown in Table 1.*

Table 1 Classification Standards of Groundwater Quality According to EWQI [6].

EWQI	Rank	Water Quality
< 25	I	Excellent quality
25–50	II	Good quality
50–100	III	Medium quality
100–150	IV	Poor quality
> 150	V	Extremely poor quality

III. RESULTS AND DISCUSSION

The minimum and maximum values of each of the parameters for each season, and their respective standards, are presented in Table 2. The TDS values ranged from 28 - 520 mg/L and 20 – 520 mg/L in the dry and rainy seasons, respectively. The pH values of the samples fell within the range of 6.9 to 7.4 for both seasons, indicating neutral to alkaline water conditions. Hardness ranged from 6 mg/L to 364 mg/L and 7 to 372 mg/L in the dry and rainy seasons. A significant amount (97.5%) of the water samples in both seasons is associated with soft- fresh water origin on TDS vs Total Hardness plot (Fig. 3) [11]. Chlorine (Cl^-) concentrations varied from 10 to 360 mg/L in the dry season to 14 to 361 mg/L in the rainy season. Nitrate (NO_3^-) ranged from a minimum of 0.2 mg/L to a maximum of 52.3 mg/L, and 0.4 mg/L to 60.3 mg/L in the dry and rainy seasons, respectively. The results were compared with the World Health Organisation (WHO) [8] and Standard Organisation of Nigeria (SON) [7] standard values. According to WHO [8], 2% of water samples surpassed the recommended nitrate limit of 45 mg/L while according to the SON [7], 100% exceeded limit of iron (0.3mg/L), rendering them unsuitable for drinking purposes. Chlorides are found in higher concentrations than WHO standard in some samples. Chlorides are among the most prevalent harmful

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL877

contaminants in groundwater. While they naturally occur in groundwater, high concentrations can be detrimental [7].

Based on EWQI, 2%, 16%, 51%, 18% and 13% of samples are Excellent, Good, Medium, Poor and Extremely Poor water quality, respectively for drinking purpose. The Entropy water quality index (WQI) map was prepared using ArcGIS to decipher the various quality classes viz. excellent, good, poor, very poor and unsuitable at each hydro-sampling site for drinking purpose. We also made a graphical representation of the EWQI levels of the samples that are collected at the different locations around the dump site for both seasons. The WQI Map of the study area indicates that most of the is having excellent to medium quality levels of groundwater while very poor to extremely poor quality is prevailing in small pockets very close to the dumpsite and at the southern parts (Fig. 4). The map clearly indicates that the quality of groundwater in the study area belongs to all quality categories shown in Fig. 5 with respect to potability for the consumption of human. The heterogeneous distribution of water quality levels, ranging from excellent to extremely poor, may be as a result of the dispersion of groundwater age in the aquifer system [10]. This kind of dispersion may cause differing exposure times to contaminants and varying levels of natural attenuation, resulting in localized impacts of contamination influenced by groundwater flow patterns and seasonal precipitation variations.

Table 2 Minimum and Maximum pH, Total Hardness, Total Dissolved Solids (TDS), Alkalinity, Electrical Conductivity (EC), Turbidity and Concentrations of Anions and Cations in Groundwater Samples around Awotan Dumpsite for Dry Season (n=45) and Rainy Season (n=45).

	Dry Season		Rainy Season		Quality Standards
pH	6.9	7.4	6.9	7.4	6.5-8.5 [8]
EC	30.0	780.0	32.0	777.0	1000 [8]
TDS	20.0	520.0	28.0	521.0	500 [7]
Hardness	6.0	364.0	7.0	372.0	150 [7]
Alkalinity	6.0	376.0	6.0	380.0	-
Turbidity	0.0	60.3	1.8	62.1	5 [7]
HCO_3	6.0	376.0	9.0	379.0	75 [8]
SO_4	2.0	240.0	10.0	248.0	20 [7]
Cl	10.0	360.0	14.0	361.0	200 [7]
NO3	0.2	52.3	0.4	60.3	10 [8]
F	0.0	0.1	0.0	0.1	150 [8]
Na	5.8	190.9	7.3	178.9	100 [7]
K	1.6	266.5	2.6	259.5	250 [7]
Ca	0.8	134.9	1.8	142.9	1.5 [7]
Mg	0.2	6.0	0.8	6.2	<45 [8]
Fe	0.5	21.9	1.3	22.7	0.3 [7]

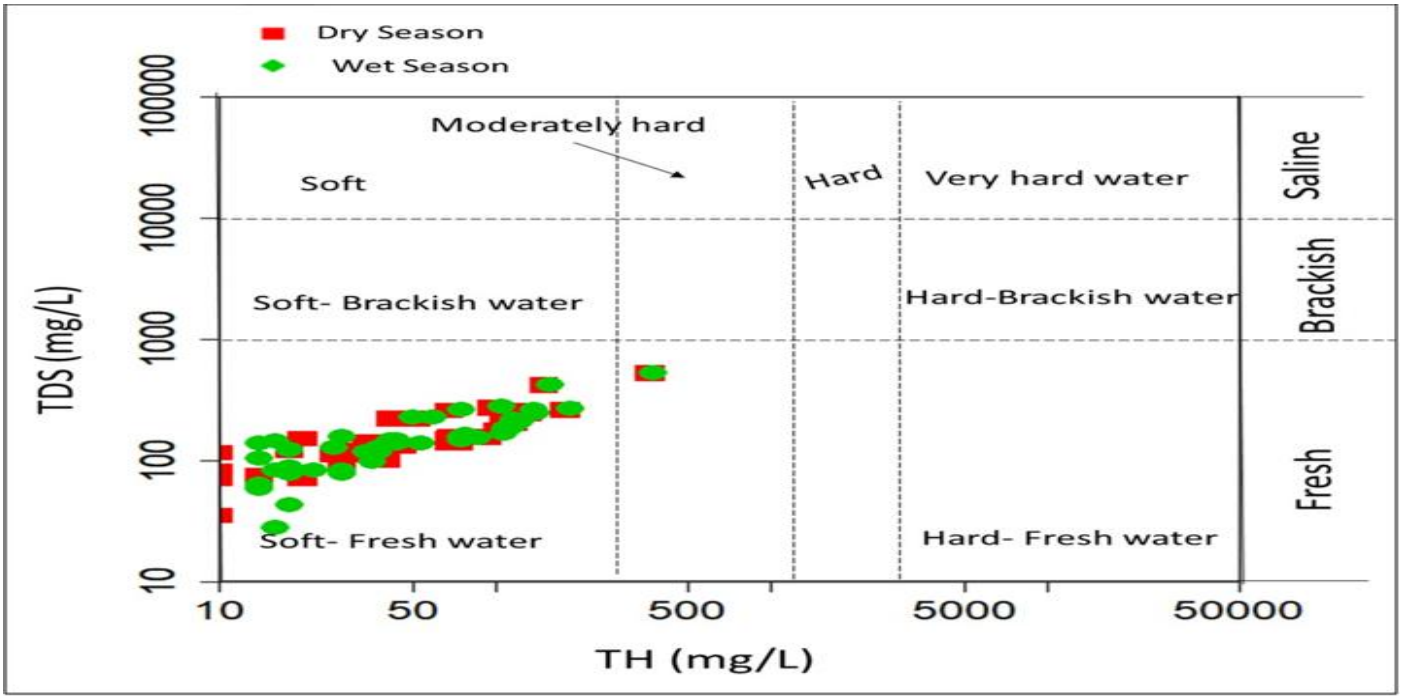

Fig 3 TDS vs Total Hardness [11] for Groundwater Samples Obtained During Dry and Rainy Seasons around Awotan Dumpsite

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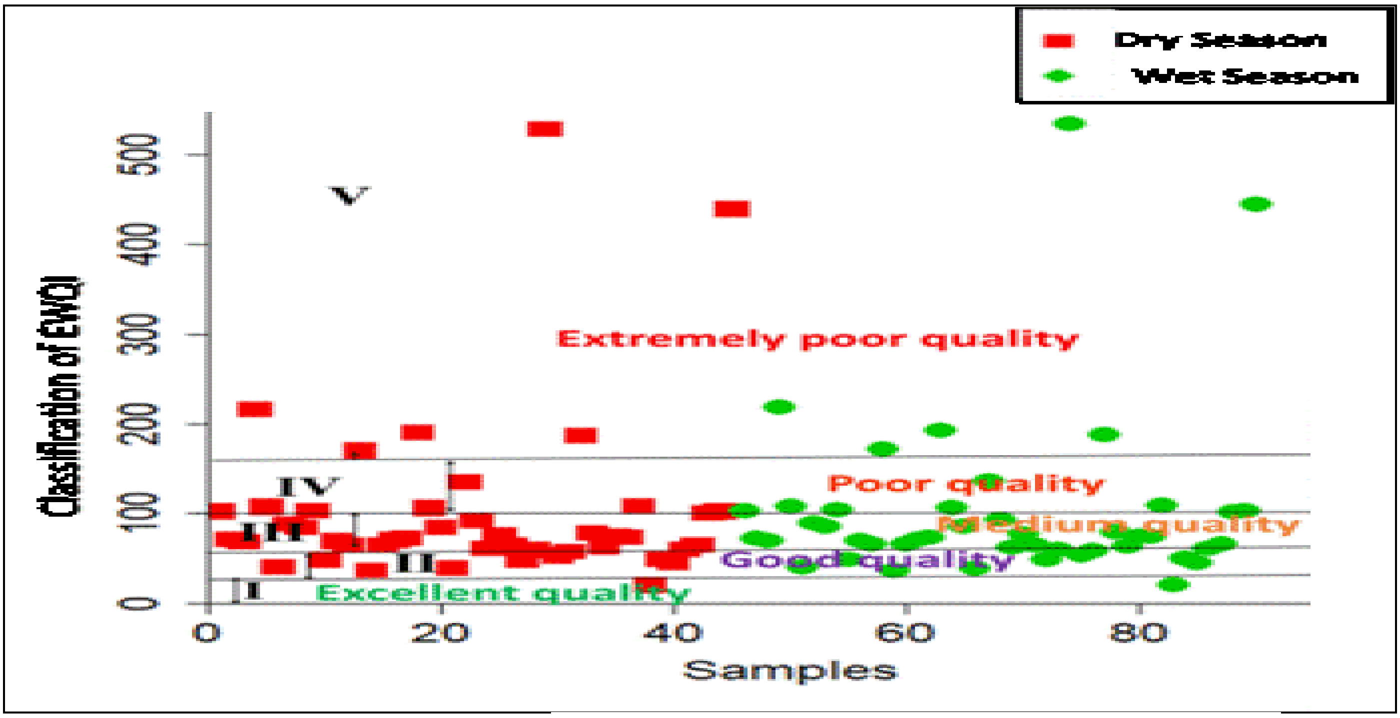

Fig 4 EWQI values of the Groundwater Samples Around Awotan Dumpsite for Dry Season (Red) and Rainy Season (Green) and its Classification.

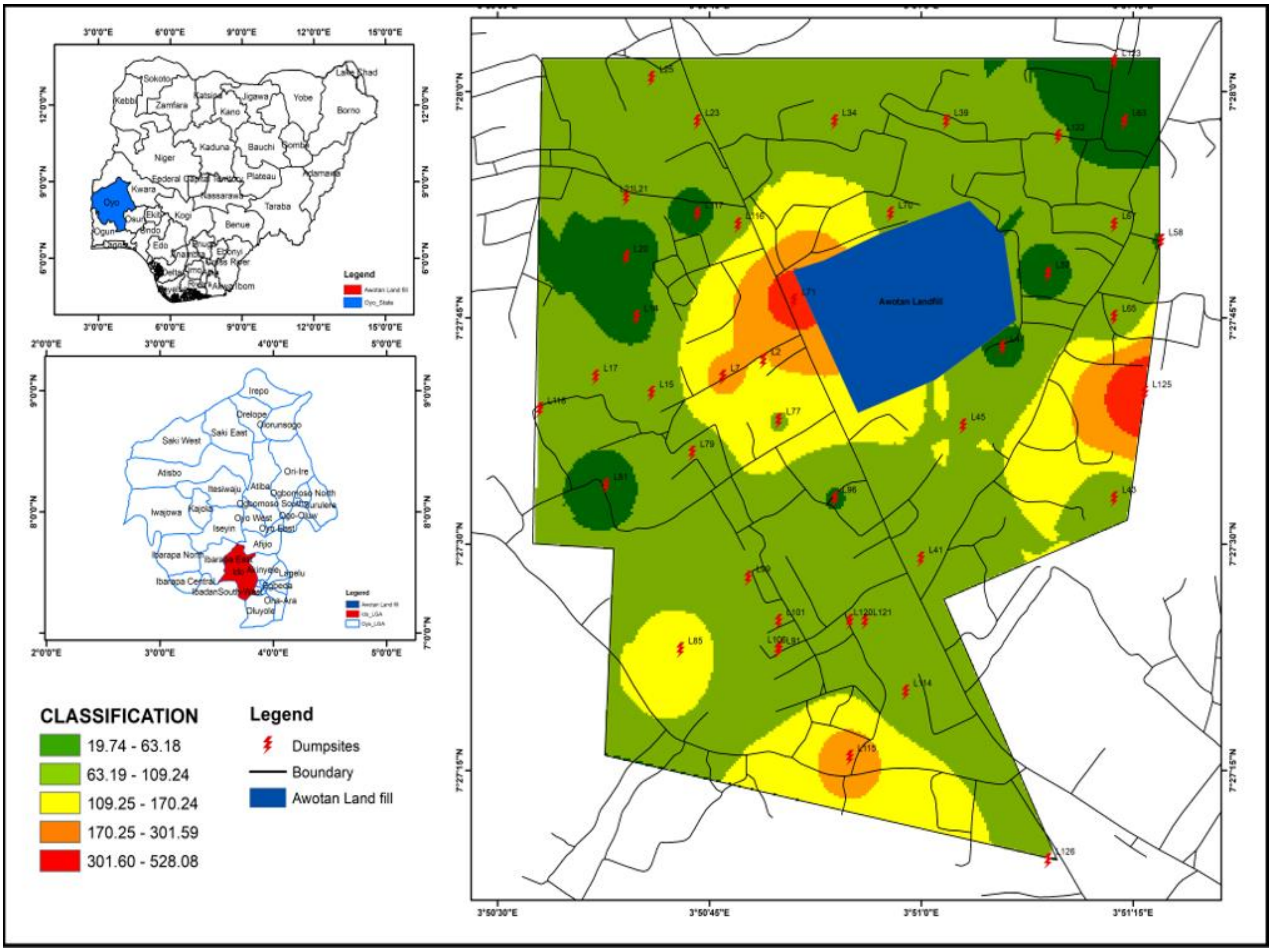

Fig 5 EWQI Spatial Distribution Map for Groundwater around Awotan Dumpsite.

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IV. CONCLUSIONS

In this study, the physio-chemical parameters were examined, and characteristic values were analysed using an EWQI. EWQI classified the groundwater samples as 2% excellent, 16% good, 51% medium, 18% poor and 13% extremely poor in terms of water quality for domestic use. The entropy water quality index levels were found to be high in some samples. This is likely due to leachate from the municipal dumpsite. These findings draw attention to the urgent need for comprehensive groundwater monitoring and management strategies.

We recommend that the government implement a sustainable retrofitting technique to enhance the existing landfill design, which should include the integration of an effective leachate collection system. This will help mitigate groundwater pollution and prevent the contamination of local water bodies. Additionally, residents near the dumpsite should adopt water treatment measures to improve water quality and reduce public health risks.

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