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Assessment of the Physicochemical and Heavy Metal Parameters of Groundwater Quality in Halls of Residence:Landmark University, Omu-Aran, Nigeria

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Abstract— In Nigeria, groundwater contamination is a critical health concern due to poor waste disposal and inconsistent monitoring. This study underscores the need for water assessment, specifically examining borehole water quality within Landmark University in Omu-Aran to identify risks and ensure safe drinking water. it aims to offer novel, site-specific evaluations of borehole water quality across five strategic locations within the study area. Sampling locations include four male hostels (Daniel, Joseph, Abraham, Isaac) and the campus water factory. For three weeks, 12 water samples were collected using repeated sampling techniques. Parameters analyzed include turbidity, color, pH, electrical conductivity (EC), total dissolved solids (TDS), chemical oxygen demand (COD), dissolved oxygen (DO), major ions (Cl^-, SO_4^{2-}, NO_3^-, PO_4^{3-}), and heavy metals (Pb, Cd, Cr, Ni, Fe). Laboratory analysis followed standard methods recommended by the American Public Health Association (APHA), Nigerian Standard for Drinking Water Quality (NSDWQ), World Health Organisation (WHO) and heavy metals were tested, using Atomic Absorption Spectrophotometry. The results indicated that most of the physicochemical parameters were within the WHO permissible limits, with pH (5.88-6.92), TDS (8.48-94.17 mg/L), DO (5.10 to 5.73 mg/L), EC (12.08-134.57 µs/cm), and nutrient ions including chloride (Cl^-), sulphate (SO_4^{2}), nitrate (NO_3^-), phosphate (PO_4^{3-}), remaining within safe limits. Heavy metals like lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni) and iron (Fe), also complied with safety standards. However, Ni levels in samples SD_2 and SD_3 (0.03±0.00) exceeded the WHO threshold of 0.02 mg/L, revealing a localised contamination hotspot that poses potential health risks. In conclusion, while water at Landmark University was generally safe for use, the elevated Ni level calls for remedial measures such as ion exchange or adsorption to mitigate contamination. Periodic monitoring of water quality is recommended to ensure long-term safety and compliance. Combining scientific rigour with localised environmental insight, this study offers a replicable model for proactive water quality management in institutional and community settings.

Keywords: Heavy metals, clean water, borehole, physicochemical parameter, health risks.

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I. INTRODUCTION

Access to clean and safe water for consumption and domestic use remains a central pillar of public health, human survival and sustainable development goals (SDGs), particularly SGD 6, which aims to ensure sustainable management of water and sanitation for all [1], [2]. In Nigeria, access to portable water remains a daunting challenge. According to recent statistics, 48% of the population (about 67 million people) rely on surface water, while 57% (around 79 million people) depend on borehole water as their primary source for daily use [3]. However, the quality of these water sources, especially groundwater accessed through boreholes, often perceived as safer due to natural filtration has increasingly come under scrutiny owing to growing anthropogenic pressures from poor waste disposal practices, and insufficient water quality monitoring [4], [5], [6], [7], [8].

Water quality is determined by a wide range of physicochemical and heavy metals parameters, including but not limited to pH, Ni, Fe, [9], [10], [11]. In extreme concentrations, these parameters could render water unsuitable for consumption, causing health hazards such as gastrointestinal illness, skin diseases, reproductive issues and even carcinogenic effects [12], [13]. Furthermore, water quality degradation is not only corrosion, scaling and deterioration of water supplied, but also compromises infrastructure, leading to deterioration of the water supply system [14], [15], [16], [17].

While several assessments have been conducted across different Nigerian communities and higher institutions [18], [19], [20], [21], [22], [23], [24], [25], there remains a notable geographical gap, as limited studies have specifically examined borehole water quality within the Omu-Aran region, Landmark University. This underrepresentation highlights the need for a localised investigation that can inform institution-specific water management strategies and contribute to regional environmental health data.

Borehole water serves as a primary source of water for students residing in the university halls of residence. Unfortunately, despite the robust guidelines from global bodies such as the World Health Organisation (WHO) [13], the U.S. Environmental Protection Agency (USEPA) [14], and the Nigerian Standard for Drinking Water Quality (NSDWQ) [15], there remains poor enforcement and inconsistency in the regular water quality assement accoss educational institutions [26].

This study addresses these critical gaps by assessing the water quality of borehole water used in selected student hostels at Landmark University, Omu-Aran, Kwara State. Via physicochemical characteristics determination using the water quality index, and heavy metal levels (atomic absorption spectrophotometer apparatus was employed), following standard analytical protocols and SPSS for statistical comparisons between observed samples and WHO standards

Most values conformed to WHO guidelines; however, nickel concentrations in samples SD_2 and SD_3 (0.03 mg/L) exceeded the permissible limit (0.02 mg/L), indicating potential localised contamination. Target remediation using ion exchange or adsorption, alongside continuous monitoring, is recommended.

II. Materials and Methods

A. Sampling Locations

The selected study area was Landmark University, Omu-Aran, Kwara State, North Central region of Nigeria, latitude 8.1211° or 8° 7' 16'' north, Longitude 5.0806° or 5°4'50'' East, 564m above sea level. Specifically, hostels (Daniel Hall A block laundry, Abraham Hall A block laundry, Joseph Hall A block laundry, Isaac Hall A block laundry and the control water factory).

Fig 1: Map showing study areas within Landmark University

B. Sampling Design and Collection

The sampling design for this evaluation includes the collection of borehole water samples from four male hostels and the water factory at Landmark University, Omu-Aran, Kwara State. Twelve samples were collected over three weeks for each sampling location, repeatedly at the same time to ensure consistency. Sampling locations include specific blocks (Daniel Hostel, Abraham Hostel, Joseph Hostel, and Isaac Hostel) and the water factory, which serves as control sites SD_1, SD_2, SD_3, SD_4, and SD_5, respectively.

Table 1: GPS locations and Geocodes for sampling locations.

S/No	Sampling location codes	Geocode	Longitude (ºE)	Latitude (ºN)
1	SD_1	439J+PF2	5°04'51"	8°07'08"
2	SD_2	439M+895	5°04'59"	8°07'04"
3	SD_3	439M+4MF	5°05'01"	8°07'02"
4	SD_4	439M+F5J	5°04'57"	8°07'06"
5	SD_5	6FW743CM+F8	5°04'59.8"	8°07'16.4"

The Borehole water samples are collected using pre-sterilised (with less concentrated HNO_3 and washed using ion-free distilled water), 750 ml well-capped bottles to prevent microbial growth. Before collection, the borehole was allowed to run for five minutes to eliminate stagnant water, and the bottles were washed with sample borehole water, removing residual contaminants. The sample was then transported in an encased container with ice at 4°C for preservation, and laboratory analysis was carried out within twenty-four hours of collection.

The analysis was conducted using a pH meter Atomic absorption spectrophotometer (AA32ON model), Palin test photometer 7100, and Multi-parameter equipment for measuring TDS and EC shown in Fig 2. These tools will enable the evaluation of physicochemical and heavy metal parameters in the borehole water samples. The study adheres to specifications of borehole water analysis as outlined by the American Public Health Association.

The sampling method as described aligns with the WHO [13], American Public Health Association (APHA) Standard Methods for Examination of Water and Wastewater, Guidelines for Drinking Water Quality [27],[28], US Environmental Protection Agency (USEPA) Guidelines for Water Quality Monitoring the random sampling [15], [14] and the use the water factory designated as the control site (SD_5) is emphasized in ISO 5667-1:2020 part 1: sampling design programs to ensure accurate interpretation of results [28]. Sample preservation and storage at 4°C in pre-sterilized bottles to prevent contamination aligns with the standard procedure of water sample preservation following the APHA standard methods [27] and WHO specifications for drinking water quality [12]. This systemic sampling and preservation approach ensures the reliability and accuracy of the data, providing an extensive evaluation of borehole water quality in the selected location.

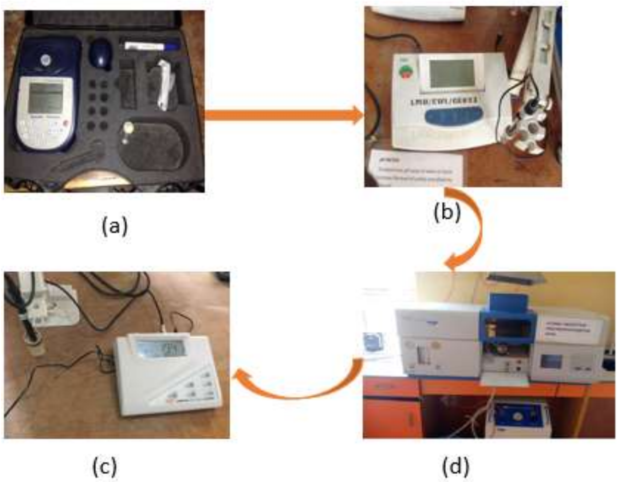

Fig 2: (a) pH meter for testing pH levels of soil, (b) Palin test photometer 7100, for analysing turbidity, dissolved solids, Nitrate, phosphate, and so on. (c) AA320N model of Atomic Absorption Spectrophotometer, for quantitative analysis of heavy metals such as Pb, Cd, Ni, Cr, Fe and so on. (d) Multi-parameter equipment for measuring TDS and EC.

C. Physicochemical Evaluation

The Borehole water samples collected were assessed for pH, odour, colour, turbidity, taste, EC, chloride, nitrate, and selected trace metals. The results are compared to the permissible value specified by WHO [12].

1) Evaluation of Colour, Odour and Taste: 10 ml volume of samples SD_1, SD_2, SD_3, SD_4, SD_5 was shaken intensely till fizzing and then left to rest. Colour assessed using the colourimetric method with the Palin test photometer 7100. 10 ml of distilled water was measured and placed in the Palin test tube during the experiment for calibrating the photometer, after which 10 ml of each sample was tested. Odour is determined via olfaction [29].

2) Determination of Turbidity: Turbidity is the muddled state of water as a result of the presence of trace microbe, dust, silt, and sand in dispersion in water bodies [30]. Turbidity assessment is carried out using a digital turbidity meter. The process includes using 20 ml of treated water placed in the turbidity meter for calibration. After which, 20 ml of the test sample was placed on the instrument, and the result was read on the NTU unit's screen [31].

3) Evaluation of Dissolved Oxygen (DO): The MW600 dissolved oxygen meter was used to assess the DO. The instrument is a digital device to measure the concentration of oxygen in borehole water samples. Firstly, the instrument was calibrated by immersing the sensor in oxygen-saturated water to adjust to standard atmospheric oxygen concentration at room temperature. The sensor was then checked, cleaned and properly fitted. DO was analysed by immersing the MW600 dissolved oxygen meter into 100 ml of each borehole water sample SD_1, SD_2, SD_3, SD_4, SD_5 and recording the readings. For accuracy, the sensor was rinsed with treated water between measurements to prevent contamination. Each sample was measured in triplicate, and an average reading was recorded as the final DO concentration.

4) Evaluation of Electrical Conductivity (EC) and Total Dissolved Solids (TDS): A multi-parameter probe was inserted into a beaker containing 20 ml of water samples each, after being calibrated with distilled water of 20 ml volume, all at room temperature. The EC value was determined for samples SD_1, SD_2, SD_3, SD_4, and $SD_{5,}$ respectively, when readings became stable. Thereafter, TDS was determined by immersing the multi-parameter sensor into 20 ml of each borehole water sample and recording the readings.

5) Evaluation of pH: The pH of the borehole water samples SD_1, SD_2, SD_3, SD_4, and SD_5 was analysed using a pH meter, the meter was calibrated using pH stabilising solutions of 7,4, and 10. The sensor is then rinsed with potable water and placed into the sample to remove alkalinity that may alter the sampling values, Reading was obtained when the meter is stable [32][12].

6) Evaluation of Chemical Oxygen Demand (COD): The COD of the borehole water sample are determined via the colourimetric test method. Palin test photometer 7100, COD digestion unit, COD splash guard, pipette, COD analysis reagent, beakers, and sample tube stand. The procedure involves preparing a blank sample with distilled water and then digesting each sample with COD reagent at 150°C for two hours. After digestion, the sample is cooled to 25°C and measured using a palin test photometer 7100, which displays the COD value in mg/L. This method quantifies the oxygen required to oxide organic and inorganic matter in water, providing a measure of water pollution [18].

7) Chemical Analysis of Phosphate (PO_4), Nitrate (NO_3), Chloride (Cl^-), Sulphate (SO_4^{2-}) and other parameters: Chemical analysis test was conducted to determine parameters such as PO_4, NO_3^-, Cl^-, SO_4^{2-}, Fe and others. The COD of the borehole water sample was determined via the colourimetric test method, the procedure involved preparing a blank by filling a test tube with distilled water 10 ml of distilled water and another with the sample borehole water. A tablet of the respective element was crushed, added and mixed thoroughly to dissolve. After allowing the solution to stand for one minute for full-colour development, the photometer was calibrated using the blank, after which the samples were inserted and tested for each parameter, respectively; the concentration mg/L was displayed on the photometer.

For exchangeable cations, an atomic absorption spectrophotometer was used to calculate their concentrations. The process was consistent across all parameters, with the only variation being the specific reagent used for each parameter. For instance, in the case of Fe, the photometer was set to measure Fe, and the same steps were followed to obtain the reading.

The method provides a reliable and standardised approach for quantifying chemical parameters in water samples, ensuring accurate assessment of water. It should be noted that Cl^- concentration of more than 250 mg/L results in the brackish saline taste of water, which renders it undesirable [33], [34], [9].

D. Heavy metal analysis

The analysis of heavy metals, Pb, Cd, Cr, Fe, and Ni was conducted using the AA32ON Atomic Absorption Spectrophotometer. This instrument measures heavy metal elements in samples via spectrophotometric analysis. Graphite absorption cell was used for the electrothermal aerosolizer and pure acetylene for the eluent gas. Based on the principal law of the Brown Bill which is expressed

$$A = \log\left(\frac{I_o}{I}\right) = KCL \qquad (1)$$

Where: I_o= Incoming light level
I = Outgoing light level
K = Absorption coefficient
C = Amount of the element
L = Path length of the light via the sample

Concentration was determined using a calibration curve derived from standard solutions. The analysis followed the APHA standard method [35]. A one-mole Nitric acid was diluted with 69.75 ml of 65% Nitric acid in 800 ml of ion-free water and thoroughly mixed. the solution was left to cool at 25°C, and ion-free water was included to bring it to the final solution of 1000 ml.

For the preparation of the 0.1mg/L (ppm) stock solution of metals, 80 L of the prepared one-mole nitric acid was transferred into a clean and dry 100 ml flask. A 10µL aliquot of a 1000 ppm metal salt standard, for instance Pb, and Cd was added using a micropipette. The solution was mixed well by shaking, and the flask was filled to 100 ml with an additional one-mole nitric acid solution. The solution was stored and allowed to cool until ready for use. This procedure was repeated to prepare stock solutions at volumes of 0.2, 0.4, 0.6, 0.8 and 1.0 mg/L.

1) Determination of lead (Pb): Amid heavy metals, Pb is foremost because of its high toxicity, even at trace concentration, it is accentuated as one of the ten most hazardous environmental chemical poisons [36]. Pb bioaccumulates in human body tissues, causing serious health risks, such as cancer, neurotoxicity and more extreme health risks [37], therefore is a need for regular Pb monitoring in borehole water. The quantitative assessment of lead concentration in the sampling area was conducted using the AA320N model of Atomic Absorption Spectrophotometer, water samples were pretreated via acid digestion with nitric acid to remove organic and release metal ions [38]. The result shows a consistent Pb concentration of 0.00 mg/L for samples $SD_1 – SD_5$ respectively, falling with the acceptable limits of 0.01 mg/L by WHO and Nigerian standard for drinking water quality (NSDWQ) [15], [39]. This indicates that the borehole water samples are excellent and free from lead contamination.

2) Determination of Cadmium (Cd): Cadmium leaches into groundwater primarily via contact with soil contaminated with fertilisers, and hydrocarbons, mainly in agricultural and production industries. High levels of Cd can disrupt hormones and enzymes, leading to severe health risks such as Kidney failure [40], [38]. its concentration within the sampling locations $SD_1 – SD_5$ was recorded at zero level. Which indicates no Cd in the sampling locations? However, regular monitoring and environmental control should be ensured to keep consistent safe limits.

3)Determination of Chromium (Cr^-): Chromium evaluation involves the classification and quantification of concentration in borehole water samples. Firstly, samples were collected and digested using nitric acid to release Cr^- content. AA320N Atomic Absorption Spectrophotometer was used to measure the chromium level. Cr^- contamination is often a result of industrial activities such as mining operations, leather tanning, metal fabrications, dye manufacturing and improper management of chromium-based waste [41]. The health risks associated with excess chromium exposure include skin irritation, cancer, respiratory diseases, and kidney diseases. Although chromium in the oxidised state Cr^{3+} is an essential nutrient in small concentrations. Therefore, regular monitoring and proper waste management practices are required to control chromium contamination [42].

4) *Determination of Iron (Fe):* Fe is slate-hued in colouration in its pure form in groundwater as ferric hydroxide Fe $(OH)_3$. [43], the results show iron concentration ranging from 0.03 to 0.09 mg/L for each sample's SD_1 - SD_5 respectively, within the acceptable limit of 0.3 mg/L in accordance with WHO. Lead levels above 0.3 mg/L may result in the weathering of Fe mineral or its leaching into groundwater, posing significant threats such as liver disease, and arteriosclerosis [44]. Laboratory techniques conducted are the AA320N model of Atomic Absorption Spectrophotometer, along with standard sample preparation, calibration and quality control procedures.

5) *Determination of Nickel (Ni):* Ni is a naturally occurring metal, but its presence can pose serious health challenges if the concentration exceeds permissible limits. The procedures for testing include a collection of samples from the five sampling locations SD_1, SD_2, SD_3, SD_4, SD_5, respectively. The samples are filtered to remove suspended solids, and nitric acid was added to prevent precipitation and stabilise nickel ions. AA32ON Apparatus was calibrated using known concentrations of Ni solution. The atoms of the sample absorb light at a specific wavelength, this absorption value is then measured and compared to the calibrated value to determine the parameter's concentration in the samples [45].

E. Data Analysis

Data analysis was conducted using SPSS software (Version 25.0). One-way ANOVA was employed to compare parameters across water samples from different sampling points. Post-hoc analysis using Duncan's multiple range test (at a 5% significance level, $p < 0.05$) revealed differences in average parameter values between locations. Results are presented as descriptive statistics and compared to World Health Organisation (WHO) guideline limits.

III. RESULTS

A. Physicochemical Parameter

The physicochemical properties of the water samples from the boreholes of the landmark university hostels and the water factory SD_1, SD_2, SD_3, SD_4, and SD_5 examined in this study, are shown in Table 1 below.

1) pH

pH results reveal the mean values are 6.18± 0.10, 6.16 ± 0.11, 6.92 ± 0.26, 6.13 ± 0.16, and 5.88 ± 0.59 mg/L for each sample's SD_1 - SD_5 respectively, values fell within the WHO limits (6.5-8.5) as the results showed the values from control as the lowest pH of the water samples collected. High pH causes an unpalatable taste, skin, and eye irritation, and reduced effectiveness of disinfection, such as chlorine [46].

2) SO_4

SO_4^{2-} values ranged between 15.67± 0.58, 13.67 ± 0.58, 13.33 ± 0.58, 13.67 ± 0.58, and 6.67 ± 1.15 mg/L for samples SD_1 - SD_5, the result varies significantly from each other, although fell within the WHO acceptable value of 250 mg/L in drinking water. Excessive levels of SO_4^{2-} value are attributed to the increased microbial activities due to solid waste deposits, which, if ingested, can act as laxatives, causing dehydration and diarrhoea. Therefore, monitoring and managing sulphate levels, particularly in areas with significant waste deposits, is essential [47].

3) NO_3

NO_3^- mean values recorded are 1.13± 0.12, 1.23 ± 0.06, 0.97 ± 0.06, 0.13 ± 0.06 and 0.67 ± 0.12 mg/L for each sample's SD_1 - SD_5, respectively; these values fell within the WHO standard value of 24.08 – 50 mg/L. NO_3 is usually harmless at permissible limits; however, at high concentrations, it can pose serious health and environmental risks. while the current nitrate levels in the analysis are within safe limits, continuous monitoring and preventive measures are essential to mitigate the risk of nitrate contamination [48],[7].

4) PO_4

All water samples analyzed for PO4 reveal that the mean values are 0.15 ± 0.01, 0.15 ± 0.01, 0.15 ± 0.01, 0.17 ± 0.01 and 0.11 ± 0.01 mg/L for each sample's SD_1 - SD_5 respectively, these values are slightly above the benchmark of 0.1mg/L, which indicates a minor contamination or environmental influence. PO_4 are not toxic to people or animals, but concentrations exceeding 1.0 mg/L are common causes of eutrophication and algal blooms, which can indirectly affect human health via the production of toxins and degradation of water quality [19], [47], therefore, there is the need for monitoring and controlling PO_4 levels.

5) CL^-

Cl^- ranged between 8.00 ± 0.00, 6.33 ± 0.58, 5.33 ± 1.15, 5.67 ± 0.58 and 2.00 ± 0.00 mg/L for each sample's SD_1 - SD_5, respectively. these values were lower than 250 mg/L, which indicates WHO acceptable limits. Excessive levels of Cl^- may cause toxicity in plants, therefore reducing crop yield. Other related side effects may include dry skin, stomach and diarrhoea as a result of chlorine ingestion. Therefore, continuous monitoring is essential to ensure consistency of safe limits [48].

6) TDS

TDS results reveal that the mean values are 77.63 ± 8.39, 74.50 ± 4.31, 94.17 ± 8.55, 74.03 ± 4.94, and 8.48 ± 0.81 mg/L for each sample SD_1 - SD_5, respectively, which is within the WHO limits of 300 mg/L for excellent water. High TDS in water indicates the presence of contaminants, resulting in unpleasant taste and odour. Despite the values falling within the WHO limits, results varied similarly with each other except the result from Dniel Hall, which had the highest value, and the control, which had a significantly lower value in comparison because it had been treated and processed [48],[47].

7) EC

EC results show values ranging from 110.63 ±12.27, 105.8 ± 6.16, 134.57 ± 11.95, 105.23 ± 7.45, and 12.08 ± 1.76 µS/cm for each sample's SD_1 - SD_5, respectively. The results varied significantly from each other, although the values fell within the acceptable range for EC in drinking water (400 µS/cm at room temperature), which indicates low mineral content in the sampling location. Generally, the number of dissolved solids in water determines the EC. High conductivity is not necessarily a cause for concern, however, dissolved ionizable solids cause water hardness or alkalinity [48], [49].

8) DO

DO results revealed that the mean values are 5.47 ± 0.12, 5.20 ± 0.10, 5.43 ± 0.06, 5.73 ± 0.12, and 5.10 ± 0.10 mg/L for each sample's SD_1 - SD_5, respectively. The value fell within WHO permissible DO levels > 5 mg/L and is considered good for drinking water, ensuring palatability and preventing taste and odour for excellent water. High DO in water indicates the presence of contaminants [49].

Table 2: Physicochemical analysis of water samples collected from the sampling points.

Parameter	SD_1	SD_2	SD_3	SD_4	SD_5	WHO[14]
	$\ddot{x}\pm\sigma$	$\ddot{x}\pm\sigma$	$\ddot{x}\pm\sigma$	$\ddot{x}\pm\sigma$	$\ddot{x}\pm\sigma$	
pH	6.92 ± 0.26^b	6.16 ± 0.11^a	6.13 ± 0.16^a	6.18 ± 0.10^a	5.88 ± 0.59^a	6.5 – 8.5
SO_4 (mg/L)	13.33 ± 0.58^b	13.67 ± 0.58^b	13.67 ± 0.58^b	15.67 ± 0.58^c	6.67 ± 1.15^a	250

NO_3 (mg/L)	0.97±0.06^{b}	1.23±0.06^{c}	1.13±0.06^{bc}	1.13±0.12^{bc}	0.67±0.12^{a}	50
PO_4 (mg/L)	0.15±0.01^{b}	0.15±0.01^{b}	0.17±0.01^{c}	0.15±0.01^{b}	0.11±0.01^{a}	0.01 – 0.5
Cl^- (mg/L)	5.33±1.15^{b}	6.33±0.58^{b}	5.67±0.58^{b}	8.00±0.00^{c}	2.00±0.00^{a}	250
T.D.S (mg/L)	94.17±8.55^{c}	74.50±4.31^{b}	74.03±4.94^{b}	77.63±8.39^{b}	8.48±0.81^{a}	300
EC (μs/cm)	134.57±11.95^{c}	105.8±6.16^{b}	105.23±7.45^{b}	110.63±12.27^{b}	12.08±1.76^{a}	400
COD (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0
DO (mg/L)	5.43±0.06^{b}	5.20±0.10^{a}	5.73±0.12^{c}	5.20±0.10^{a}	5.10±0.10^{a}	5
Colour (TCU)	0	0	0	0	0	-
Turbidity (NTU)	0	0	0	0	0	1-5

World Health Organisation maximum permissible limits [12], each value recorded for the study areas represents the mean of four sampling points ± standard deviation (that is ẍ±σ = mean plus or minus standard deviation), different letters across rows within the same heavy metal represent a significant difference. Significant at ($p<0.05$), Significant at ($p<0.01$).

B. Heavy Metals

Heavy metal evaluation results are presented in Table 2.

1) Lead (Pb)

The results for Lead show that the mean values ranged between 0.0007±0.0006, 0.0003±0.0006, 0.0003±0.0006, 0.0007±0.0006, and 0.0±0.0 mg/L for each sample's SD_1 - SD_5, respectively. The values are all within the WHO limits of 0.01 mg/L for drinking water. Lead in the water supply appliance and inlet pipes can adversely contribute to health issues, such as bioaccumulation in humans and plants, especially if heavy metals such as nitrates are present [36], therefore, continuous monitoring and maintenance are required to ensure it is consistently within the WHO limit [48].

2) Cadmium (Cd)

Cadmium mean levels ranged from 0.00±0.00, 0.00±0.00, 0.00±0.00, 0.00±0.00, and 0.00±0.00 mg/L for each sample's SD_1 - SD_5, respectively, at all sampled locations, values showed no less than ($p<0.05$). Therefore, the mean level of Cd was within the WHO permissible limits (3 µg/kg or 0.003 mg/L), hence, the borehole water is clean for drinking and safe for municipal usage [48].

3) Chromium (Cr)

chromium mean values ranging from 0.03±0.00, 0.03±0.00, 0.03±0.00115, 0.03±0.00153, and 0.0177±0.00115 mg/L for each sample's SD_1 – SD_4 respectively. Chromium heavy metal is easily transmitted from soil to the surface via runoffs, which also infiltrate into groundwater. A high concentration of this in drinking water may result in health risks such as allergic dermatitis in humans [48].

4) Nickel (Ni)

Nickel results show that the mean values ranged from 0.02±0.00, 0.03±0.00, 0.02±0.00, 0.03±0.00058, and 0.02±0.0006 mg/L for each sample's SD_1 - SD_5, respectively. The water samples SD_1, SD_3 and the control SD_5 had the least Ni concentration, and they were exponentially similar, all within the WHO limits. The values were within the 0.02 mg/L, but samples SD_2, SD_4 were above the WHO limits of >0.02 mg/L. This may be a result of the leaching of metals in contact with the sampled water, secondary causes may include the breakdown of nickel ore rocks and minerals. In excess, it may lead to carcinogenicity, raising the risk of cancer, allergies, lung fibrosis and other conditions in humans. Therefore, recommended monitoring and control should be ensured [48].

5) Iron (Fe)

The mean levels of Fe ranged from 0.09±0.003, 0.11±0.01, 0.10±0.002, 0.10±0.002, and 0.03±0.003 mg/L for each sample's SD_1 - SD_5, respectively. Iron at the various sampled locations showed that the values are all within the WHO limits of <0.003 mg/kg [48].

Table 3: Heavy metal parameter of the study area.

Parameter	**SD_1**	**SD_2**	**SD_3**	**SD_4**	**SD_5**	**WHO**
	ẍ±σ	**ẍ±σ**	**ẍ±σ**	**ẍ±σ**	**ẍ±σ**	
Lead (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.05
Cadmium (mg/L)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.003
Chromium (mg/L)	0.03±0.00^{b}	0.03±0.00^{d}	0.03±0.00^{c}	0.03±0.00^{c}	0.01±0.00^{a}	0.05
Nickel (mg/L)	0.02±0.00^{b}	0.03±0.00^{c}	0.03±0.00^{c}	0.02±0.00^{b}	0.02±0.00^{a}	0.07
Iron (mg/L)	0.10±0.00^{c}	0.11±0.01^{d}	0.09±0.00^{bc}	0.09±0.00^{b}	0.03±0.00^{a}	0.3

Each value under the study areas represents the mean of five sampling points ± standard deviation (that is, $\ddot{x} \pm \sigma$ = Mean ± Standard Deviation). Different letters across rows within the same heavy metal represent significant differences; at $p<0.01$ and $p<0.05$ [7]. A graph showing the results of heavy metals parameters in comparison with WHO standard.

CONCLUSION

This study assessed the quality of borehole water in the hostels of Landmark University, Omu-Aran, Nigeria, by analysing its physicochemical and heavy metal parameters. Water samples from four hostels SD_1–SD_4 and compared with a control sample SD_5 of treated water, with results evaluated against WHO standards.

The physical parameters, including TDS, pH, turbidity, and electrical conductivity, were generally higher in hostel samples SD_1–SD_4 than in the control SD_5 but remained within permissible limits. Chemical parameters, such as DO, COD, EC, phosphate, chloride, and sulfate, were also within WHO standards, though chloride levels in SD_4 were elevated, likely due to local contamination from toilet waste and soap water.

Heavy metal analysis revealed that all samples met WHO guidelines, except for nickel in SD_3 (0.03 mg/L), which slightly exceeded the permissible limit (0.02 mg/L), suggesting potential contamination from supply pipes. Cr- levels were comparable to the control, while Pb, Cd, Ni, and Fe, showed slightly higher values in hostel samples than in the treated water. The borehole water is generally safe for consumption; however, the presence of elevated Ni in SD_3 and localized Cr contamination in SD_4 necessitate further monitoring. A long-term assessment is recommended to identify potential sources of contamination and ensure sustained water quality in the hostels.

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