Nigerian Journal of Science and Engineering Infrastructure (NJSEI)

Volume 1, Issue 1 (2023), 157-173.

Physiochemical Quality Assessment of Surface and Groundwater Sources: A Case Study of Southwest, Nigeria

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ABSTRACT
Surface and ground waters can originate from rain, the ocean, glaciers, lakes, ponds, wells, rivers, springs, and boreholes, among other places. These waters must be pollution-free for them to be useful. For this reason, the study evaluated the quality of water samples from three states and identified pollution based on physicochemical characteristics. In all, thirty-four water samples (dug well, rivers, borehole, and rain) were obtained from Osun, Ondo, and Ekiti State, and on-the-spot determinations of pH, electrical conductivity (EC), total dissolved solids (TDS), and temp (temperature) using a portable multi-parameter meter (the Temp/pH/TDS/EC meter), was made to measure the pH, temperature, TDS, and electrical conductivity in situ. The mean results were as follows: pH (6.87), temperature (28.17 °C), TDS (126.71 mg/L), and electrical conductivity (253.06 µs/cm). There were correlations (EC has a high positive association with TDS (r = 0.999, Cl = (0.998, 1.000) and a modest link with Temp (r = 0.233, Cl = (-0.106, 0.528). It should be noted that there were weak relationships between pH and temperature (r=0.139), TDS (r=0.027), and EC (r=0.022)) and the cluster analysis showed only a cluster of the water sample locations. The investigation revealed that the physicochemical were within the acceptable ranges of the World Health Organization (WHO) and the Nigeria Standard for Water Quality (NSDWQ).
Keywords: Water samples, different purposes, WHO, NSDWQ, pollution-free, natural and artificial activities

INTRODUCTION
Water is life and every living thing is composed of water. Water must be sourced at all costs for our continuous living. Surface and ground waters can originate from rain, the ocean, glaciers, lakes, ponds, wells, rivers, springs, and boreholes, among other places. These waters must be pollution-free for them to be useful and water contamination is still a significant issue on a global scale (Lodder et al., 2010; Vadde et al., 2018). It is crucial to assess the quality of surface waters in drinking water sources since they might serve as sources of dangerous substances and harmful microorganisms. To reduce possible threats to

DOI.org/10.61352/2023AT12

public health, it is crucial to pinpoint the source(s) of pollution and create effective management plans. Point sources and nonpoint sources of pollution both have an impact on the quality of the surface water in an area (Nnane et al., 2011). According to Vadde et al. (2018), nonpoint sources (NPS) are runoff associated with specific land use patterns such as urban (e.g., stormwater, sewage overflows), agricultural (e.g., fertilizers, pesticides, animal manure), or forestry land uses. Point source pollution results from a single identifiable source, such as effluents from industries and wastewater treatment plants (Bu et al., 2014).To protect the population from waterborne diseases and to develop effective preventive measures, water quality monitoring, and sanitary risk identification are crucial. For evaluation and monitoring, it is crucial to comprehend the geographical and temporal fluctuations in physicochemical and microbiological parameters because environmental systems like rivers and lakes are impacted by many sources (Razmkhah et al., 2010).

As stated by Chinedu et al. (2011), streams, rivers, boreholes, and wells are the sources of drinking water in Africa, Latin America, and Asia. These sources are untreated and may pose several health problems. Numerous organic, inorganic, and biological contaminants affect natural water. Lead is the most well-known dangerous heavy metal and is toxic at low quantities (Chinedu et al. 2011; Alemu et al. 2017). Even at low concentrations in drinking water, metals have an accumulative effect. According to Alemu et al. (2017), food chain translocation may also exacerbate toxicological effects in people in other instances, the pollutant is not poisonous, but its presence causes circumstances that are harmful to water quality (Erikson et al. 2005). For instance, pH must remain constant within a range that is advantageous to the specific organisms involved. Grave pollution issues from land drainage are exacerbated by the rising use of commercial fertilizer and the widespread use of a variety of organo-pesticides, insecticides, herbicides, and weed killers in agricultural techniques (Nag and Suchetana 2016). Because most contaminants are resistant to natural deterioration, this sort of agricultural pollution has effects on water contamination (Erikson et al.2005; Nag and Suchetana 2016).

Physico-chemical, microbiological, and biological factors are used to determine the quality of water. Options are available for measuring changes in water quality using microbial and non-microbial factors (Edberg et al., 2000, Liu et al., 2011). Temperature, dissolved oxygen, pH, electrical conductivity, total hardness, total suspended particles, chloride, and various nitrogen species, including nitrate, nitrite, and ammonia, are some of the physicochemical parameters (Goshu and Akoma, 2011).

The health state of the citizenry is influenced by the quality of their water, hence monitoring public health requires the evaluation of physicochemical qualities and trace element levels. When assessing the quality of water, understanding the hydrochemistry of surface waters is crucial, particularly in rural areas where people utilize water for both home and agricultural uses (Chebet et al., 2020).

In almost every application involving water quality, pH assessment is an important component. High or low pH readings in environmental sampling and monitoring might be a sign of contamination. A measure of water quality is electrical conductivity. Data obtained for conductivity are used to assess water cleanliness, identify pollutants, and assess solution concentration. A material's conductivity determines how well it can move electrical current. Simple plates or wires are inserted in the sample, a potential is supplied across them (often a sine wave voltage), and the current is measured. One of water's most fundamental characteristics is temperature, and many other metrics rely on it to be accurate. The health of aquatic species and organisms can be affected by changes in the thermocline, which can be monitored using temperature data to track thermal loading or discharge. The high temperatures can be harmful to many aquatic creatures.

The determination of the physiochemical quality of surface and groundwater sources was the main topic of this study. Studies on the physicochemical characteristics of water samples have a global focus, especially in developing countries (Hoko, 2005; Goshu and Akoma, 2011; Udofia et al., 2016; Olusola et al., 2017; Vadde et al., 2018; Olusoji et al., 2019; Oloruntoba and Ogunbunmi, 2020; Chebet et al., 2020; Chakravarty and Gupta, 2021). There have been several studies on a small number of physicochemical parameters in water samples, but the data has been inconsistent, has only been collected for brief periods, and various sampling procedures were used.

Research on water samples has been described in previous studies (Abulude et al., 2017; Olasoji et al., 2019; Oluwagbayide and Abulude, 2022) to address issues including water-borne disease outbreaks brought on by consuming tainted surface and groundwater as well as elemental and physicochemical analysis. These were all examined in one place (same Local Government Areas or state). No research project went beyond a single state. As a result, research that examines all water samples from more than one state has not begun.

The goal of the study described here was to evaluate the quality of water samples from Osun, Ekiti, and Ondo States (rain, river/stream, well, borehole, and well), and to identify pollution based on physicochemical characteristics. Numerous pit toilets, subpar housing designs, a lack of potable water, and ineffective solid waste and wastewater management are some of the characteristics of the areas selected for the study. The findings of this study will help to pinpoint areas of high contamination in the water samples for future investigation and improved management. The findings presented here will be of widespread interest and relevance due to the critical problem of rising urbanization and its effects on water bodies.

MATERIALS AND METHODS

Study area

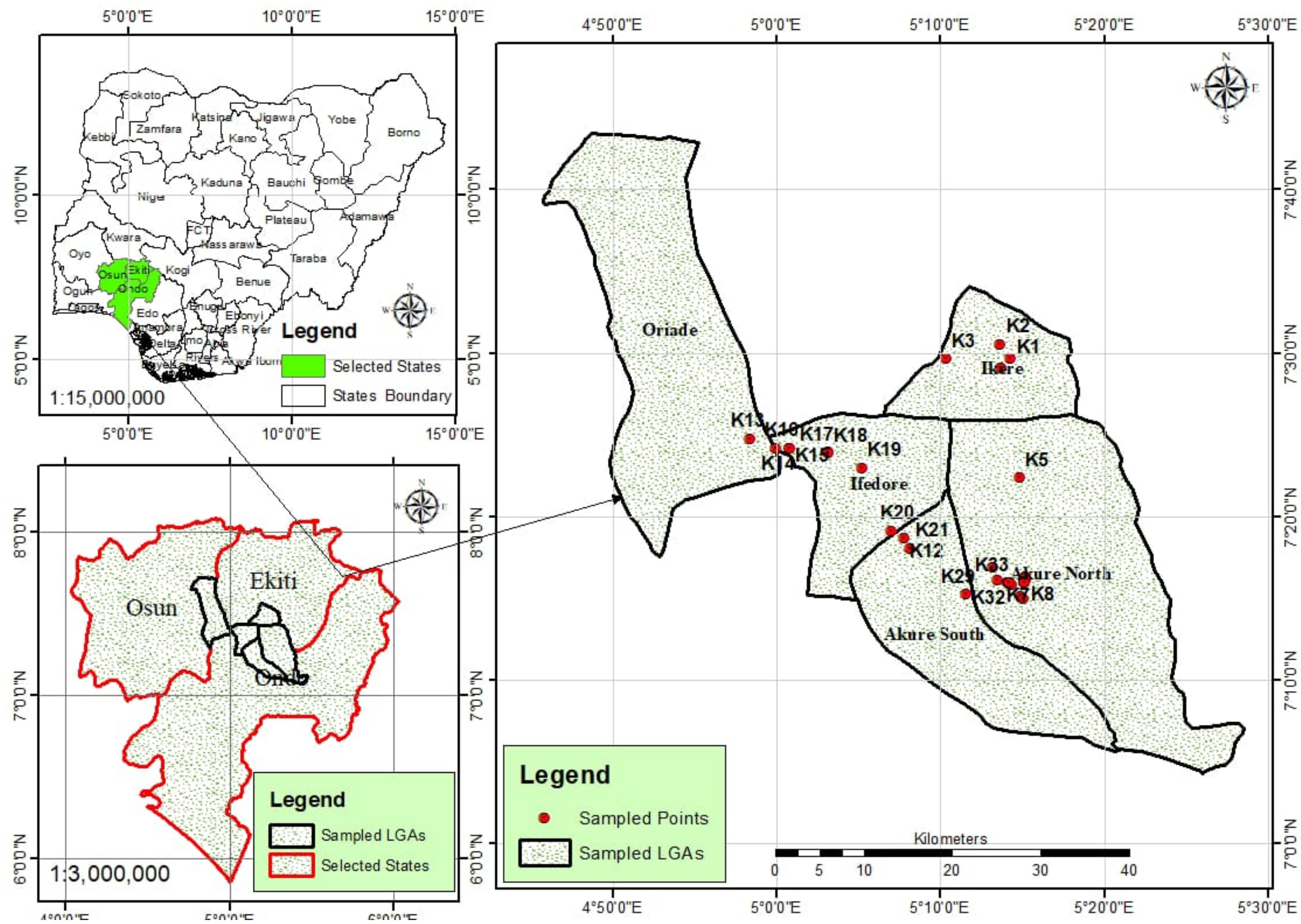


Figure 1: Sample Locations in Osun, Ekiti, and Ondo States

One of Nigeria's six geopolitical zones, the South West, represents the geographical and political entity of the country. According to Oni and Odekunle (2016), South-West Nigeria is located between latitudes 4° and 9°N and longitudes 30° and 7°E, covering an area of around 191,843 square kilometers. Six states make up this region: Lagos, Osun, Oyo, Ogun, Ondo, and Ekiti (All news, 2022). Around 22% of the nation's entire population, or 47 million people, live in the region (My Guide Nigeria, 2022). Rainy season (March to November) and dry season (December to February) in Nigeria have different weather patterns. Around this time, cold, dry winds from the northern deserts sweep towards the southern regions, bringing with them the Harmattan dust (My Guide Nigeria). Culturally, the vast bulk of the zone is located in Yoruba land, which is the native cultural homeland of the Yoruba people, the largest ethnic group in the southwest.

Sampling

Water samples from rivers, streams, wells, boreholes, and rain (34 samples) were chosen for this investigation in November 2022. Table 1 lists the details of the water samples. Eight boreholes, eleven sites from streams, two from rain, and fifteen sites were hand-dug wells (Figure 1). Samples were obtained in Osun, Ekiti, and Ondo States (Figure 1) between the hours of 7 and 10am. The area around these water samples is home to several human and natural activities. The 2.5 L of water samples were obtained and processed in polyethylene bottles that had been cleaned with distilled water and treated with nitric acid before being filtered through membrane filters with 0.45- micron pore sizes. A Garmin global positioning system was used to identify the coordinates of the sampling sites, which are displayed in Table 2, and was then placed on a map (Figure 1).

Physicochemical Measurement

A portable multi-parameter meter, the Temp/pH/TDS/EC meter, was used to measure the pH, temperature, TDS, and electrical conductivity in situ (model MI 1399). Physicochemical parameters such as the total pH, temperature, total dissolved solids, and electrical conductivity levels were determined in the on the spot immediately samples were collected (field assessment) following the operation manual.

Table 2: The codes, states, towns, types, and coordinates of water samples

Sample Location/ Code	State	Town	Type	Coordinate	
				Latitude	Longitude
K1	Ekiti	Ikere	Well	7.495	5.239
K2	Ekiti	Ikere	Stream Oke Osun (Kajola)	7.509	5.228
K3	Ekiti	Ikere	Well	7.494	5.173
K4	Ekiti	Ikere	Stream (Oke Osun)	7.485	5.229
K5	Ondo	Iju	Stream (Ono)	7.373	5.248
K6	Ondo	Akure	Well	7.268	5.254
K7	Ondo	Akure	Stream (Ogijan)	7.269	5.254
K8	Ondo	Akure	Borehole	7.266	5.253
K9	Ondo	Akure	Well	7.272	5.254
K10	Ondo	Akure	Borehole	7.271	5.254
K11	Ondo	Akure	Well	7.282	5.221
K12	Osun	Ikeji Arakeji	Borehole	7.311	5.130
K13	Osun	Ikeji Arakeji	River (Arinran)	7.413	4.973
K14	Osun	Owena	Well	7.403	4.999
K15	Osun	Owena	River(Osun)	7.403	5.014
K16	Osun	Owena	Well	7.403	5.014
K18	Ondo	Igbaraoke	Well	7.398	5.053

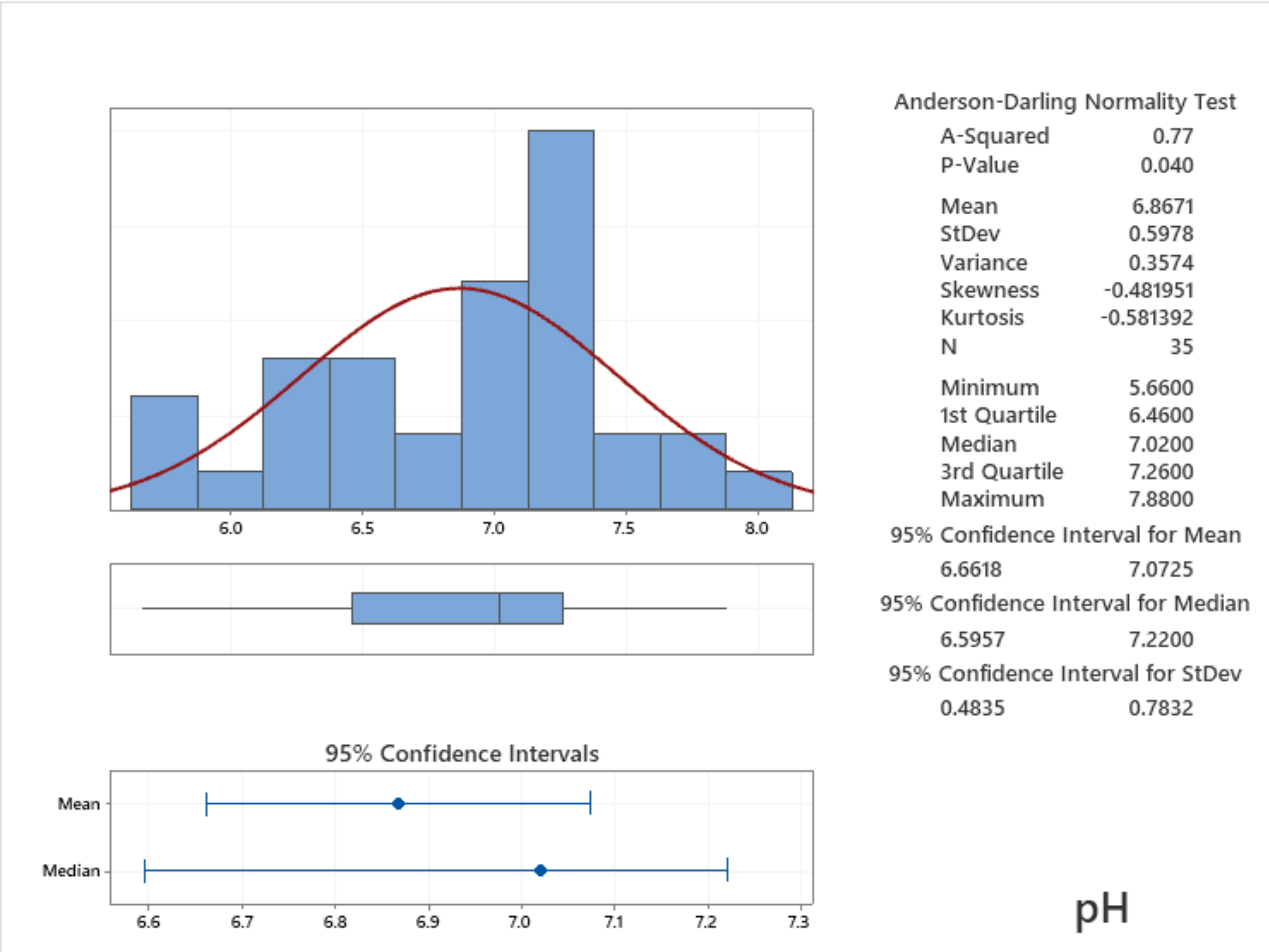
K19	Ondo	Ero	Well	7.383	5.088
K20	Ondo	Ibule	Borehole	7.319	5.118
K21	Ondo	Akure	Borehole	7.301	5.136
K22	Ondo	Akure	River (Ala)	7.269	5.226
K23	Ondo	Akure	Borehole	7.264	5.239
K24	Ondo	Akure	Well	7.264	5.240
K25	Ondo	Akure	River (Ala)	7.252	5.249
K26	Ondo	Akure	Stream	7.249	5.252
K27	Ondo	Akure	Well	7.267	5.253
K28	Ondo	Akure	Borehole	7.266	5.253
K29	Ondo	Akure	Well	7.254	5.193
K30	Ondo	Akure	Well	7.266	5.236
K32	Ondo	Akure	Well	7.266	5.236
K33	Ondo	Akure	Well	7.266	5.238
K34	Ondo	Akure	Borehole	7.266	5.238

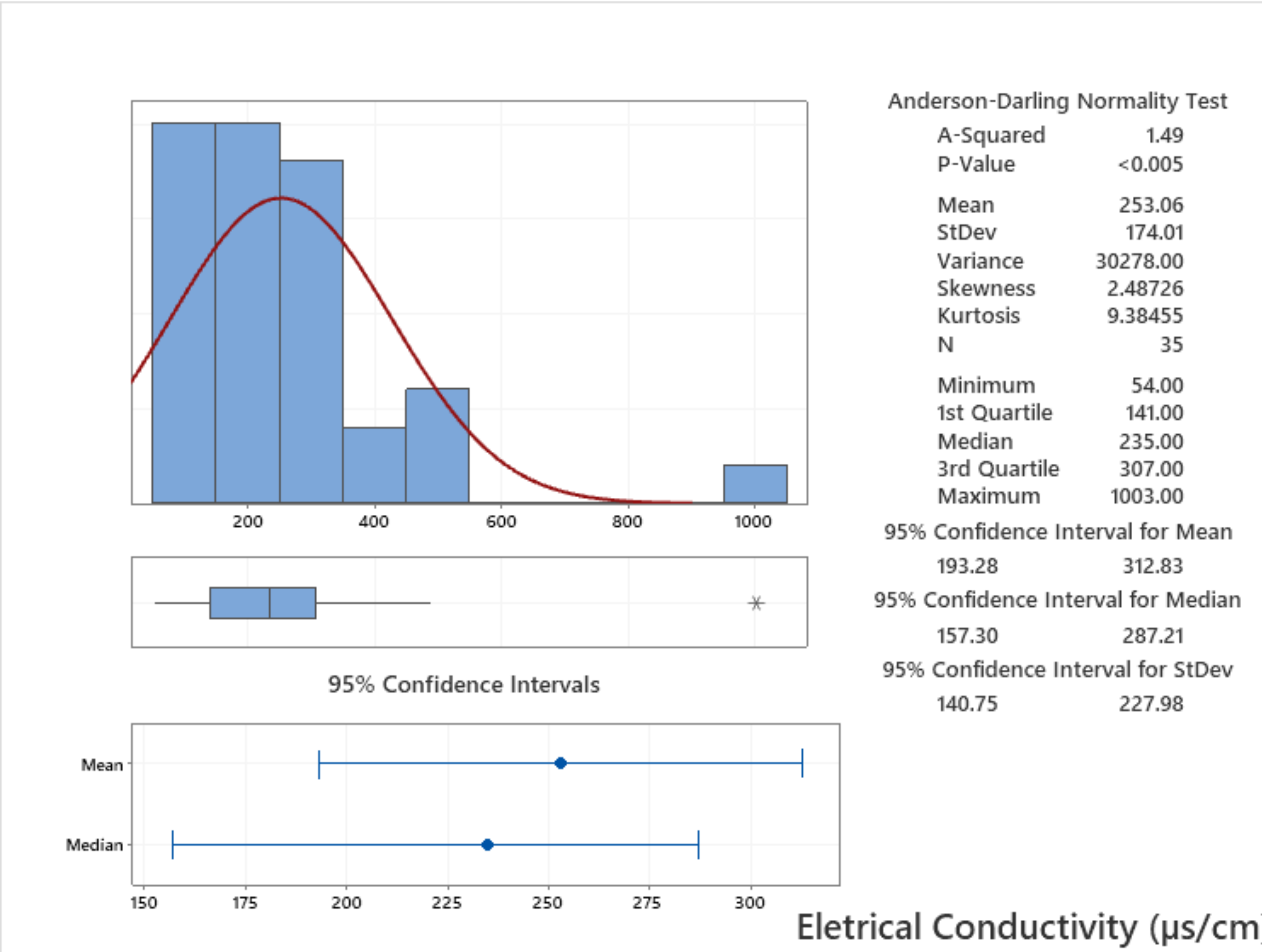
Statistical Analyses

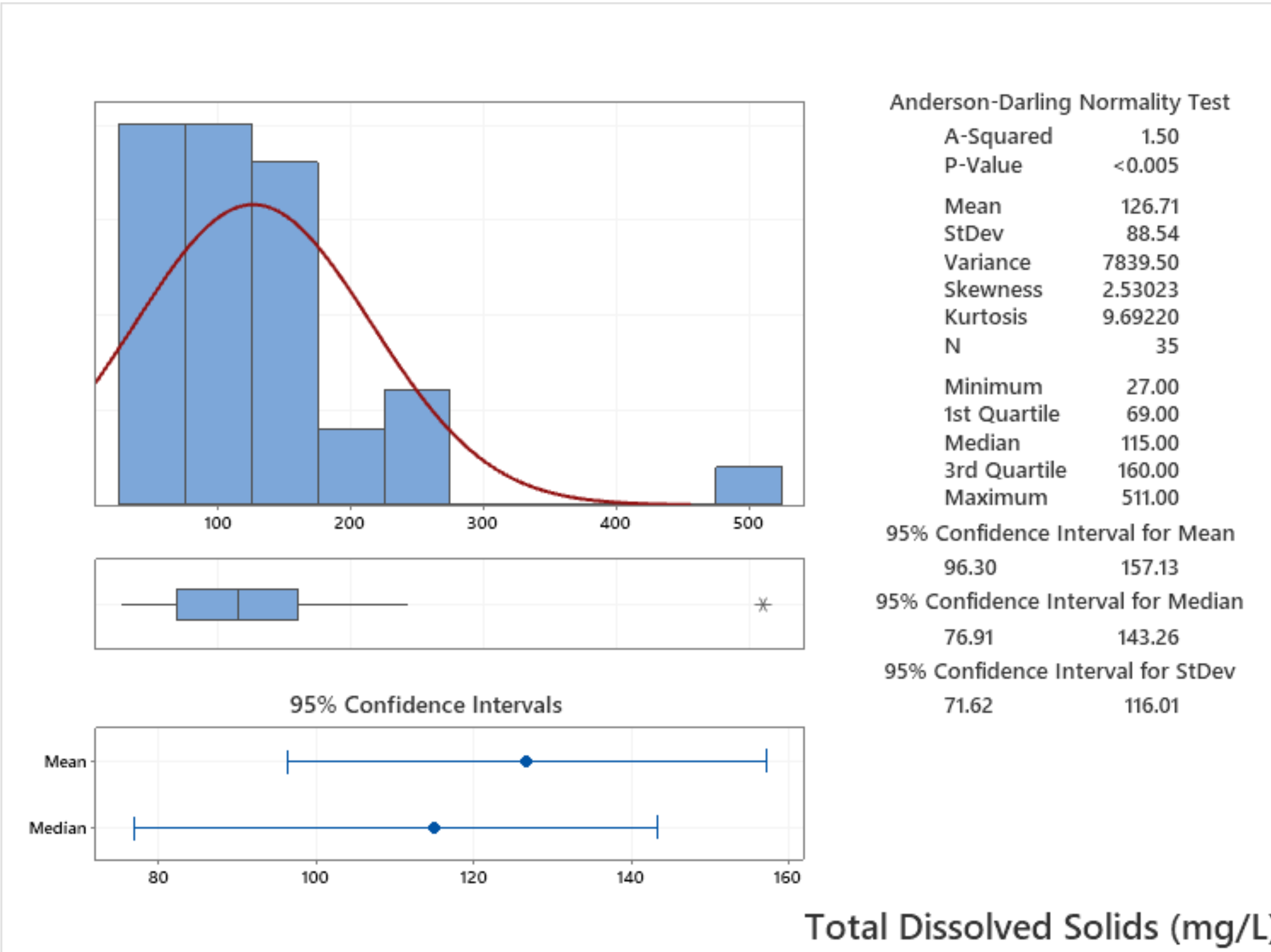
The study's data was subjected to a basic description (Anderson-Darling Normality Test). The Pearson's correlation test was used to examine the correlations between the physicochemical properties of the water samples and the differences (coefficient of variation and standard deviation) in those parameters across the sampling locations. To explore the variability of water quality and group similar sampling locations, samples were also subjected to cluster analysis. Using the normalized dataset, hierarchical agglomerative clustering was carried out. Minitab (2020) software was used to run the statistical analyses on the data.

RESULTS AND DISCUSSION

Figures 2 and 3 showed the physicochemical parameters of the water samples from the three states. The pH ranged from 5.66 to 7.88, with 6.87 as the mean. The results of the Anderson-Darling Normality test had a P-Value of 0.040. Site K21 (7.88) had the highest pH reading, and Site K9 had the lowest reading (5.66). The pH values obtained at sampling stations K8, K9, and K14 fell below the range (6.5–8.5) recommended by the World Health Organization (WHO) and the Nigeria Standard for Water Quality (NSDWQ) for drinking and irrigation water (Figure 3). The pH of the water samples did not significantly differ between the river and stream stations. In the areas near rivers and streams, the pH levels were higher. Aquatic organisms will perish if the pH of the water is either too high or too low. The solubility and toxicity of chemicals and heavy metals in water can also be impacted by pH 12. While some aquatic organisms can survive in water with pH values outside of this range, most prefer a pH range of 6.5 to 9.0 (EPA, 2012; Fondriest Environmental, 2013). Additionally, a high pH reduces the effectiveness of chlorine's disinfectant action, leaving a bitter taste in the mouth, causing deposits to build up in water pipes and on water-using appliances, and increasing the need for additional chlorine. Metals and other materials will corrode or dissolve in low pH water (USGS, 2019).


Anderson-Darling Normality Test
A-Squared 0.77
P-Value 0.040
Mean 6.8671
StDev 0.5978
Variance 0.3574
Skewness -0.481951
Kurtosis -0.581392
N 35
Minimum 5.6600
1st Quartile 6.4600
Median 7.0200
3rd Quartile 7.2600
Maximum 7.8800
95% Confidence Interval for Mean
6.6618 7.0725
95% Confidence Interval for Median
6.5957 7.2200
95% Confidence Interval for StDev
0.4835 0.7832
6.0
6.5
7.0
7.5
8.0
95% Confidence Intervals
Mean
Median
6.6
6.7
6.8
6.9
7.0
7.1
7.2
7.3
pH


Anderson-Darling Normality Test
A-Squared 1.49
P-Value <0.005
Mean 253.06
StDev 174.01
Variance 30278.00
Skewness 2.48726
Kurtosis 9.38455
N 35
Minimum 54.00
1st Quartile 141.00
Median 235.00
3rd Quartile 307.00
Maximum 1003.00
95% Confidence Interval for Mean
193.28 312.83
95% Confidence Interval for Median
157.30 287.21
95% Confidence Interval for StDev
140.75 227.98
200 400 600 800 1000
95% Confidence Intervals
Mean
Median
150 175 200 225 250 275 300
Eletrical Conductivity (µs/cm)


Anderson-Darling Normality Test
A-Squared 1.50
P-Value <0.005
Mean 126.71
StDev 88.54
Variance 7839.50
Skewness 2.53023
Kurtosis 9.69220
N 35
Minimum 27.00
1st Quartile 69.00
Median 115.00
3rd Quartile 160.00
Maximum 511.00
95% Confidence Interval for Mean
96.30 157.13
95% Confidence Interval for Median
76.91 143.26
95% Confidence Interval for StDev
71.62 116.01
100 200 300 400 500
95% Confidence Intervals
Mean
Median
80 100 120 140 160
Total Dissolved Solids (mg/L)

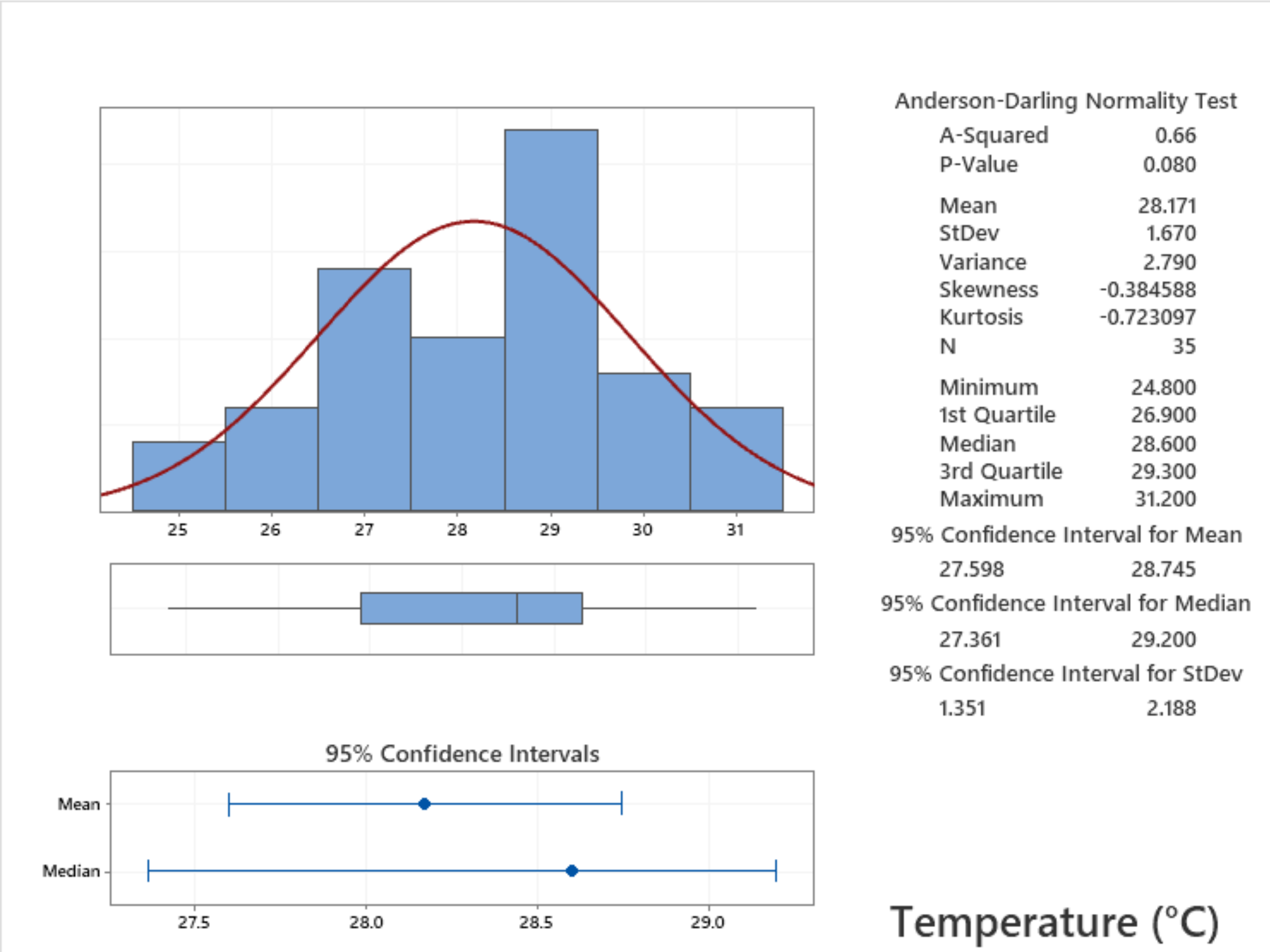


Figure 2: The Physicochemical Properties (pH, Electrical Conductivity, Total Dissolved Solids, and Temperature) of the Water Samples

The temperatures values were between 24.80 and 31.2 °C. The following values were the mean, standard deviation, variance, Skewness, and Kurtosis: 28.17, 1.67, 2.79, -0.39, and -0.72 respectively. Low variance and standard deviation indicate that there was low variation in the temperature of the water samples. Suitable drinking water should be at least 15 °C warmer than room temperature. Temperatures above 15 °C promote the growth of unwelcome organisms and may exacerbate issues with taste, odor, color, and corrosion. Cattle ingest more water when the temperature is between 4.4 to 18.3 °C, according to Chinedu et al. (2011). When the temperature is more than 27 °C, water and feed intake rates often decrease, affecting animal productivity. Without any geothermal energy present, it was anticipated that the temperature of the subsurface water would be lower than that of the surface water. This study's temperature results were comparable to 27°C (monsoon) by Chakravarty and Gupta (2021). The upkeep of streams is greatly aided by vegetation and trees, which lowers light and, in turn, photosynthesis, helps to keep the cool water temperature. Ideally, one would expect the temperature of the water samples to be lower than what were obtained in the study, due to the time of sampling which is dry season, definitely this could be the reason why temperature was high.

The electrical conductivity values were 54 to 1003 µs/cm with 141, 235, and 307 being the median, first and third quartiles, respectively. Electrical conductivity, which is determined by the concentration of ions, their total concentration, mobility, valence, relative concentrations, and temperature, serves as a criterion to evaluate the cleanliness of water (Oyem et al. 2014). Only the dug well value at position K29 exceeded the WHO recommendations for residential water (1000 µs/cm) in terms of electrical conductivity (EC). High electrical conductivity may have been caused by runoff from farms that produce food. The water is safe to drink if the conductivity readings are less than 1000 µs/cm. When the value is between 1000 and 2999 µs/cm, minor diarrhea may result, but beyond 3000 µs/cm, domestic animals may avoid drinking the water since it is thought to be a forerunner to acute diarrhea (WHO 2011). The results of this study were lower than those (260 to 1637 µs/cm) found in the river Molo water basin in Kenya by Chebet et al. (2020). In general, higher EC indicates that the water contains more electrolytes. Since the majority of salts can ionize, EC can also be used to represent the total amount of dissolved solids. High EC water is not appropriate for irrigation. As a result, EC is a significant indicator of the quality of irrigation water. The conductivity of water is crucial because it can inform you about the concentrations of dissolved compounds, chemicals, and minerals in the water. Increased concentrations of these contaminants will result in increased conductivity (EPA, 2020). An abrupt change in a body of water's conductivity can signify contamination. Due to the extra chloride, phosphate, and nitrate ions, agricultural runoff or a sewage leak will increase conductivity (Fondriest Environmental, 2013).

The average, low and high readings were 126.71, 27, and 511 mg/L, respectively of the Total Dissolved Solids (TDS). TDS according to WHO (2011), are the total amount of substances dissolved in water, including K+, Na^+, Ca^{2+}, Mg^{2+}, SO_4^2, Cl^-, PO_4^{3-} and $H_4SiO_4^{2-}$. The water analyzed had TDS levels that ranged from 79 to 823 mg/L. TDS levels above 1000 mg/L have substantial (unpalatable) impacts on the quality of drinking water (WHO 2011). For all sampling sites, the overall TDS values were determined to be within the desired range. As a result, the water is safe to consume in terms of TDS. High TDS affects the flavor, hardness, corrosion resistance, and osmoregulation of freshwater organisms, among other aspects of water quality (Prasad et al., 2019). High dissolved solids in water is known to impair physiological functions in humans and may induce gastrointestinal irritation, especially in those with kidney disease (Ramesh and Bhuvana 2012).They are also undesirable for industrial use because they can alter the flavor and appearance of finished products, cause scales, speed up corrosion, and precipitate foaming in boilers.

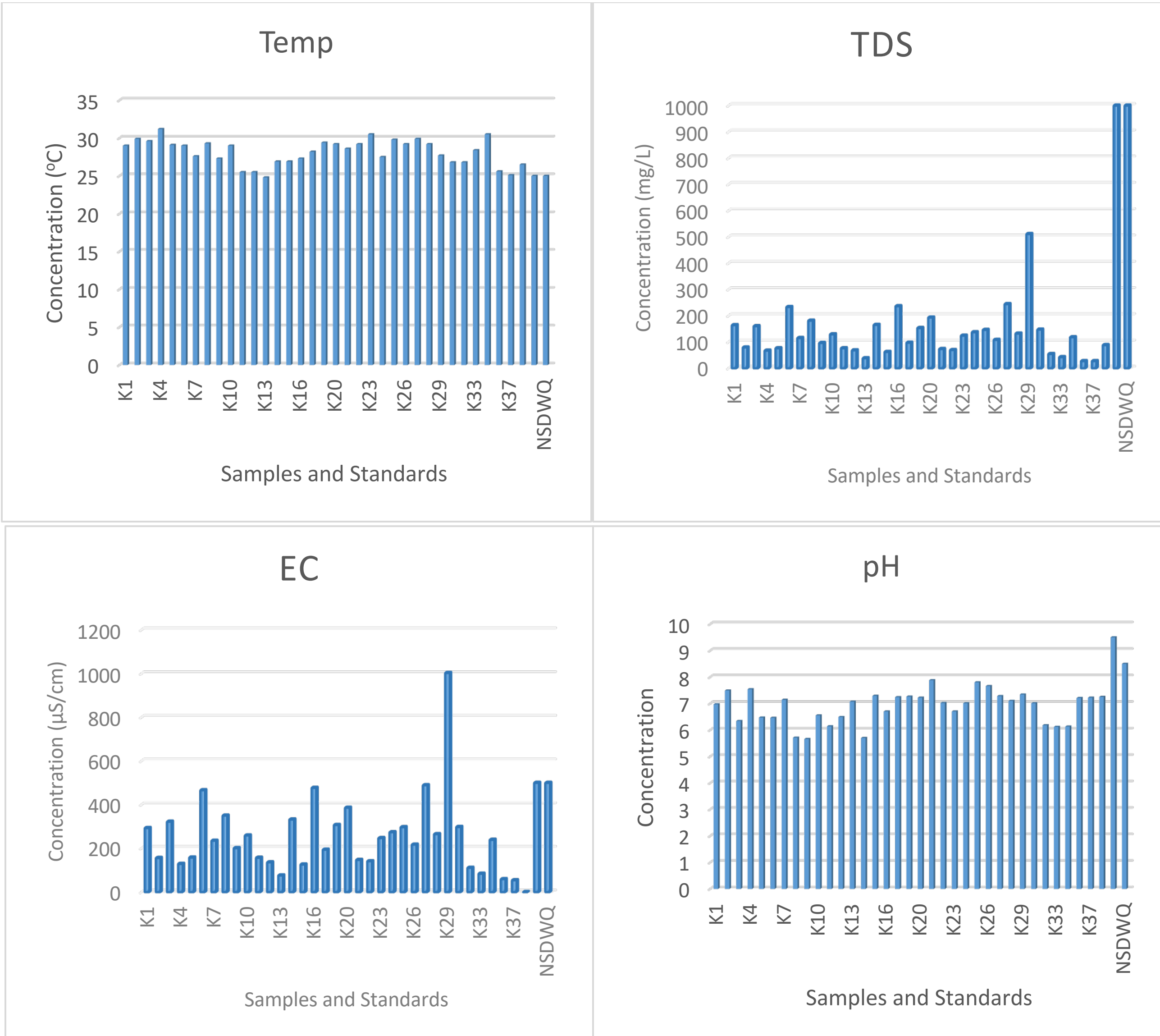


Figure 3: The Mean Levels of the Water Samples compared to Standards

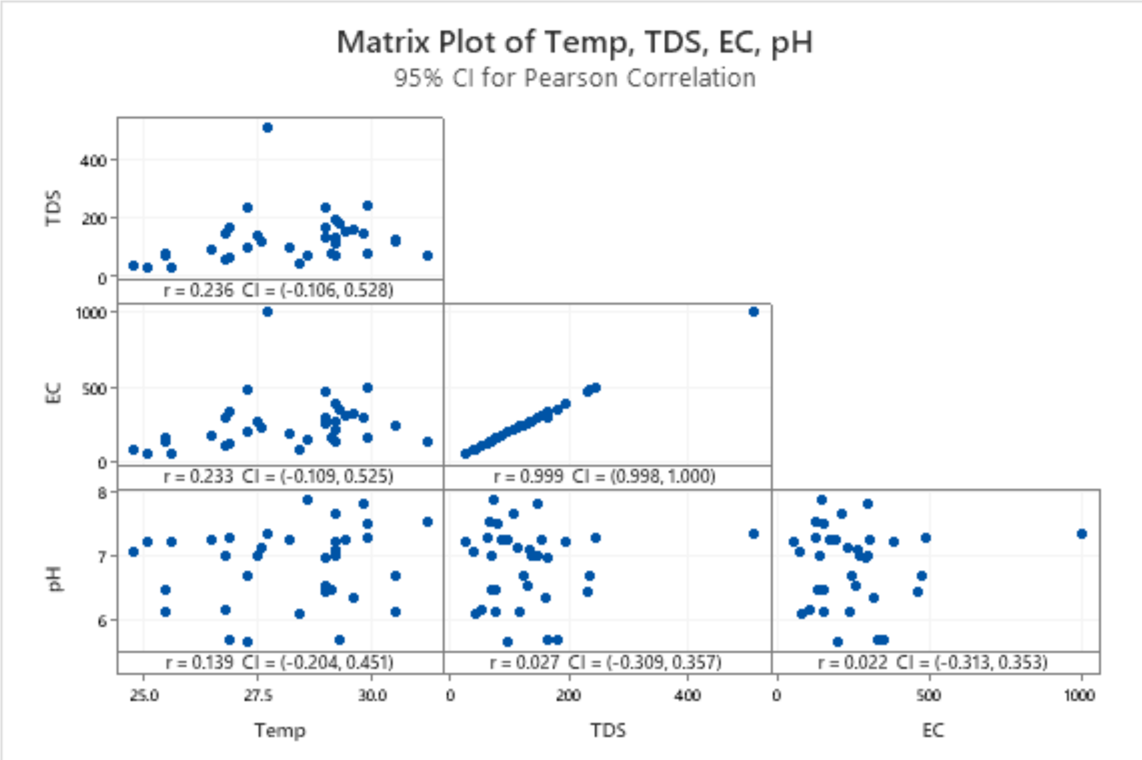


Figure 4: The Person Correlation Matrix of the Parameters

A correlation matrix with 95% confidence level for Pearson Figure 4 illustrates the correlation of the four parameters EC, TDS, pH, and temperature. High TDS in water supplies can come from both natural sources and as a result of human activities, according to the data, which revealed that EC has a high positive association with TDS (r = 0.999, Cl = (0.998, 1.000) and a modest link with Temp (r = 0.233, Cl = (-0.106, 0.528). The most frequent sources of Total Dissolved Solids in water are sewage, urban and agricultural runoff, and industrial wastewater. It should be noted that there were weak relationships between pH and temperature (r=0.139), TDS (r=0.027), and EC (r=0.022), suggesting that agricultural and urban runoff activities are likely sources of organic pollution. The World Health Organization states that a TDS concentration of 1000 mg/L is acceptable for consumers of water, but this acceptability factor may fluctuate given that the TDS concentration directly affects the flavor of water.

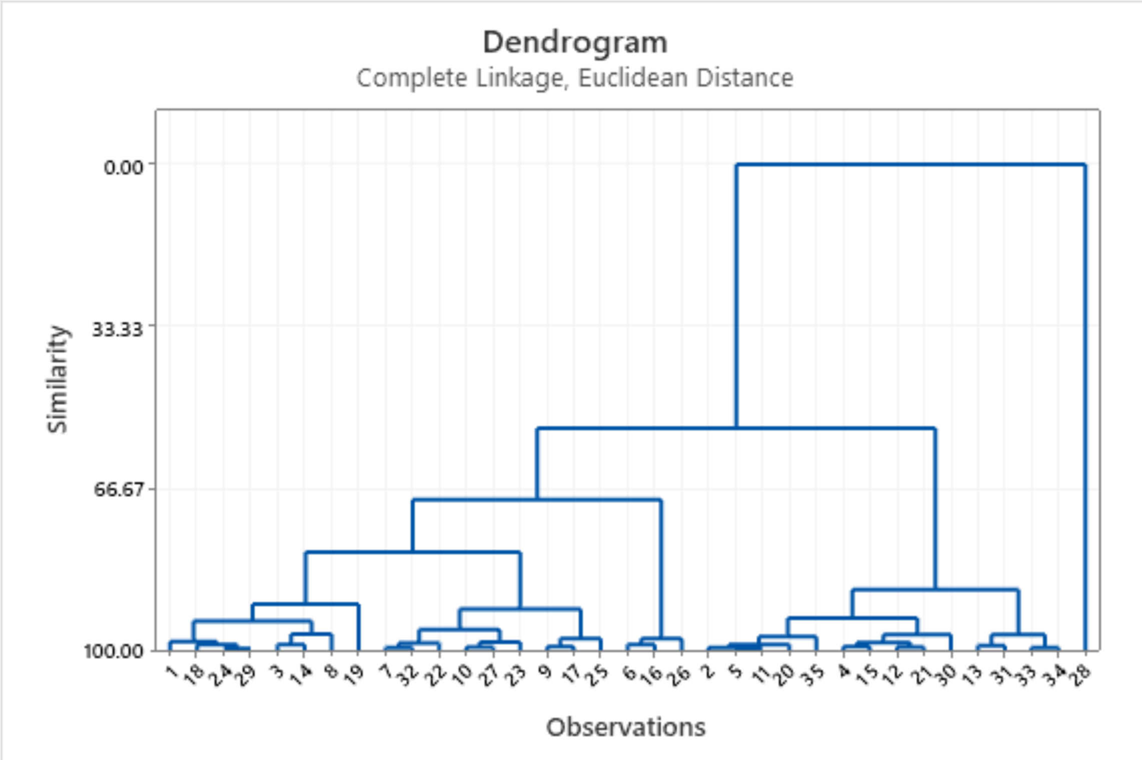


Figure 5: Cluster Analysis of the Water Quality Parameters

To group sampling sites with comparable water quality parameters, cluster analysis (CA) was used. Thirty-four (34) observations, 1296102 (cluster sum of square), 129.800 (average distance from centroid), 842.669 (maximum distance from centroid), and 1 cluster were included in the final partition of the CA (Figure 5). Each cluster was assigned to a specific category of pollution based on the physicochemical data. The locations of the cluster are as follows: (1, 18, 24 and 29); (3, 14, 8 and 19); (7, 32 and 22); (9, 17 and 25); (6, 16 and 26); (2, 5, 11, 20 and 35); (4, 15, 12, 21 and 30); (13, 31, 33, 34 and 28). These regions are primarily near residential, mixed-use, low-traffic, and cottage activity zones. The findings demonstrated that the stream stations, dug wells, and borehole sampling locations could be perfectly clustered in related or comparable pollution categories as well as the stream and ground water of the appropriate water source types. It was feasible to identify different ecosystems, land uses, and pollution patterns in the analyzed water systems from the physicochemical characterization and cluster analysis.

CONCLUSIONS

The results of this investigation showed that the pH values were within the acceptable ranges (WHO and NSDWQ), indicating that the water samples were either alkaline or acidic, probably as a result of the use of fertilizers in the neighboring farms around the study region in addition to other anthropogenic causes. Except for one location, electrical conductivity was below the allowable level (dug well). Because of the low variance and standard deviation, it was established that the total TDS values for all sampling sites fell within the acceptable range and that there was little variation in the temperature of the water samples. As a result, the water is TDS-safe for consumption. The relationship between the four parameters of EC, TDS, pH, and temperature is shown in a correlation matrix with a 95% confidence level. TDS and EC have strong positive correlations, but pH, temperature, and EC only have modest correlations. Based on the results of the physicochemical investigation, cluster analysis demonstrated that the sampling locations are grouped into a single cluster.

ACKNOWLEDGMENTS
The authors are grateful to those who assisted in the provision and collection of the water samples for the study. The contributions of the anonymous reviewers who assisted in the improvement of the manuscript are acknowledged

CONFLICT OF INTEREST
No conflict of interest

AUTHOR CONTRIBUTION
Francis Olawale Abulude and Kikelomo Mabinuola Arifalo conceived the experiment, contributed to reagents, and supervised the work; Ebenezer Alaba Adeoya contributed to reagents, materials, performed the experiments, analyzed and interpreted the data, and wrote the first draft; Olumide Oluwole Adeyemi and Bidemi Sikirat Jiddah-Kazeem contributed to data interpretation and wrote part of the manuscript.

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