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PHYSICOCHEMICAL AND HEAVY METAL CONTENT ASSESSMENT OF WATER QUALITY IN KEANA AND NASARAWA-EGGON LOCAL GOVERNMENT AREAS, NASARAWA STATE, NIGERIA

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ABSTRACT
This study conducted a thorough evaluation of the physicochemical parameters of various drinking water sources in Keana and Nasarawa Eggon, Nasarawa State. The assessment involved the use of standard methods to analyze the water samples. Additionally, the heavy metal contents were determined using the atomic absorption spectrophotometric method. The findings revealed that the pH levels ranged from 7.36 to 8.16 in Keana (KN) and 5.70 to 5.80 in Nasarawa Eggon (NE), with mean pH values of 7.74 and 5.74, respectively. The conductivity varied from 3.94 to 4.56 µS/cm in KN and 510 to 1760 µS/cm in NE. Alkalinity content ranged from 4.06 to 4.52 mgL^{-1} in KN and 45 to 50 mgL^{-1} in NE. Nitrate, acidity, chloride, phosphate, TDS, DO, and BOD levels were also assessed. The metal concentrations included Pb, Mn, Cr, Zn, Fe and Cu, and were within permissible limits, except for Pb and Ni, which exceeded WHO specifications. This study provides crucial insights into the water quality of these regions, essential for ensuring the safety of water for human consumption and other activities.

Keywords: Physicochemical, heavy metal, water sources, Keana LGA, Nasarawa-Eggon LGA

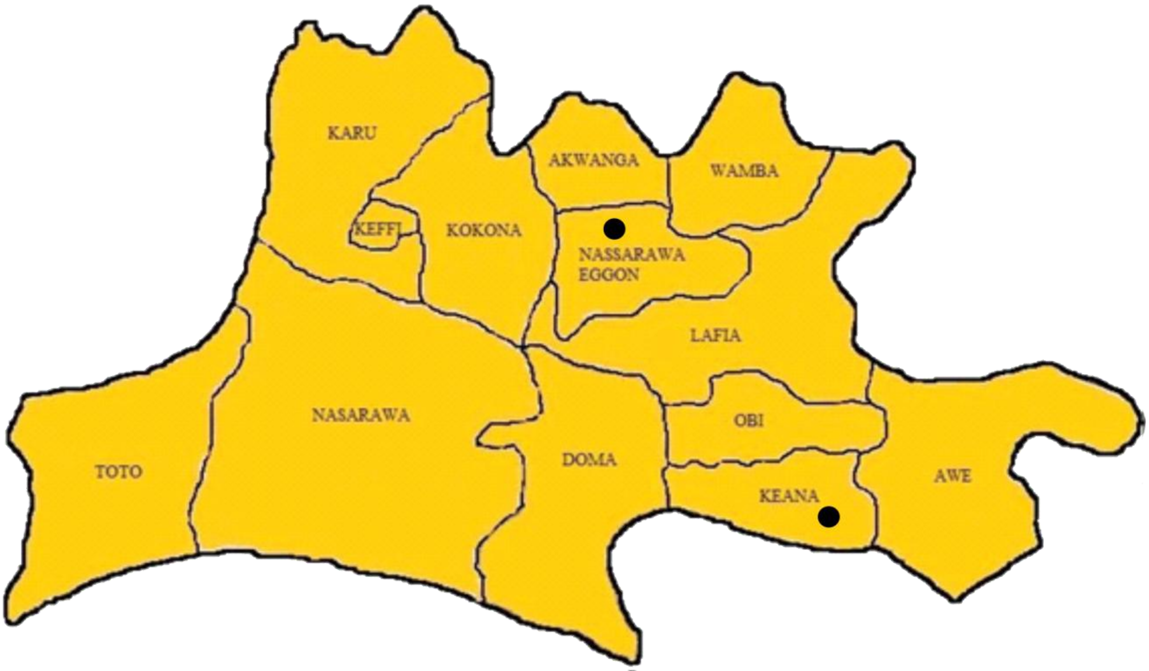
INTRODUCTION
Water is essential for sustaining life as all living organisms require it to maintain good health and vigor. It serves as a medium for both chemical and biochemical reactions that continually take place in any environmental space (Rajankar *et al.*, 2009). Ameloko and Ayolabi (2018) highlighted the significance of groundwater as a major source of fresh water and the potential impacts of pollutants and poor management on its quality. Drinking Water Quality Standards define the acceptable levels of various parameters to ensure the safety of drinking water. Groundwater is the primary source of drinking water, while surface water from natural sources generally exhibits better quality compared to areas influenced by human activities. Surface waters are often susceptible to contamination from point and non-point sources, including wastewater from agricultural and industrial activities and runoff from rainfall (Odiba *et al.*, 2017). The correlation between access to safe drinking water and the health of a population is evident, particularly in regions some regions of Nasarawa State, Nigeria (Opaluwa *et al.*, 2020). Ensuring sustainable and safe provision of potable water remains a significant global challenge. This challenge is particularly acute in rural regions of many developing nations due to inadequate water supply infrastructure (Bilewu *et al.*, 2022; Edokpayi *et al.*, 2017). Industrialization drives societal progress, significantly contributing to the economic growth and advancement of a state or country at large. Industrial activities release effluents into water bodies altering their physical, chemical, and biological properties. These discharges (treated and untreated industrial wastes) contain suspended and dissolved solids, leading to contamination of surrounding water bodies. Many Nigerian urban centers rely on water from these polluted rivers (Bilewu *et al.*, 2022; Edokpayi *et al.*, 2018).

Water pollution levels are influenced by various factors, including the presence of pollutants, their ecological impact, and water usage (Emodi, 2020; Ogah, 2020). The residence time of water in reservoirs plays a crucial role in pollution dynamics, affecting the accumulation of contaminants. Contaminants can originate from point and nonpoint sources, such as industrial activities, intensive animal farming, agriculture, urban areas, and abandoned mines (Singh *et al.*, 2016). Additionally, stormwater runoff contributes significantly to water pollution by carrying pesticides and herbicides from agricultural lands and urban areas (Bilewu *et al.*, 2022). This contamination eventually infiltrates both surface and groundwater sources (Aremu *et al.*, 2017), emphasizing the urgent need for comprehensive water quality assessments and management strategies to safeguard human health and environmental sustainability. Therefore, this study aims to conduct a comprehensive analysis of the physicochemical properties of various drinking water sources in Keana and Nasarawa Eggon, Nasarawa State, with the primary objective of determining the safety and suitability of water from these sources for human consumption and other activities.

MATERIALS AND METHODS

Sample location

The location or study area is Keana town, the Headquarters of Keana Local Government Area, and Nasarawa Eggon the Headquarters of Nasarawa Eggon Local Government Area of Nasarawa State, Nigeria (Figure 1). Keana is located between latitude 8^o 10¹N and longitude 8^o 46¹E (LGSC, 2024) while Nasarawa Eggon is located between latitude 8^o 43¹N and longitude 8^o 32¹E.



Source: Aremu *et al*. (2011)

Figure 1: Map of Nasarawa state showing the sampling locations (Keana and Nasarawa Eggon)

Sample collection

Sampling was done in the month of August 2023 and collection of samples was done in the morning. Three water samples were collected in 1 litre bottles from each location and placed in plastic bottles that have been washed and rinsed with concentrated HNO_3 to preserve water samples before they were sent directly to the lab for analysis. In Keana the three water samples were collected as SK1 streams water from Angwan Gangare Ward, SK2 boreholes water from Angwan Amiri Ward and SK3 stream water from Angwan Gangare Ward. In Nasarawa Eggon the samples were collected from three different sources namely, SN1 well water located at Kofar Sarki, SN2 Borehole water at the Local Government Secretariat and SN3 stream water located at Iyaka stream. In both cases Plastic containers were used for the collection of water samples and were labeled appropriately. It is worth noting that a portable GPS unit was used to find groundwater locations.

Analysis of physicochemical parameters

pH and Conductivity: These were done with the use of a Hanna Instruments HI 9813-6N pH/EC/TDS Meter. The meter was calibrated before the electrode was infused into the sample.

Total Dissolved Solids (TDS): A filtered water sample quantity of 50 mL was oven-dried in a beaker. The difference in the weight of the empty beaker and the oven dried content was used to estimate the TDS (Sluiter *et al*., 2008).

Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO): BOD in water is basically determined by the difference in the dissolved oxygen (DO) levels of water samples prior incubation and after 5 days of incubation. The BOD of the collected wastewater samples was determined by the dilution method. Dilution water was prepared by addition of 10 mL of each of the reagents: phosphate buffer, magnesium sulphate, calcium chloride, ferric chloride, sodium sulphite and ammonium chloride into 10 L of water. The measured volume of wastewater sample was topped up with dilution water to 1 L mark of a standard flask. Two 300 mL amber bottles were filled with the diluted water. One of the bottles was incubated at 20^{o}C for 5 days. MnSO4 solution, alkali-iodide-azide reagent and concentrated sulphuric acid were added into the other amber bottle. DO in the wastewater sample was derived through iodometric titration. For dissolved oxygen at day zero (DO_0), 50 mL aliquot of the solution was titrated against sodium thiosulphate solution using starch solution as indicator, until a colourless endpoint was attained. At the end of the 5 days, the sample in the incubator was brought out; dissolved oxygen at day five after incubation (DO_5) was determined by following the same procedure used for the determination of DO_0. A blank was prepared in a transparent bottle for DO_0. (Aniyikaiye *et al.*, 2019) Another blank was prepared in an amber bottle and incubated with the sample for DO_5:

$$BOD_5\left(mg\ L^{-1}\right)\frac{\left(DO_0 - DO_5\right)\ x\ volume\ of\ \ BOD\ bottle}{volume\ of\ \ sample}$$

Nitrate, phosphate and chloride: Nitrate, phosphate and chloride were determined using standard methods (Udo *et al.*, 2009).

Metal analysis of samples

The metals analyzed were iron, cadmium, lead, zinc, manganese and copper. The samples used for the analysis were acid preserved and digested prior to the analysis. Metal analysis was done by using atomic absorption spectrophotometer (Bulk Scientific VGP 210 model).

Statistical analysis

One way analysis of variance (ANOVA) was carried out to assess the significant differences in the data obtained. The means of the data was compared using SPSS (Statistical Package for Social Sciences).

RESULTS AND DISCUSSION

The physicochemical characteristics that were investigated in water from Keana and Nasarawa Eggon are presented in Tables 1 and 2. The average pH of the water samples ranged between 5.73 NE and 7.74 KN. The average conductivity values range from 4.33 uS/m (Keana) to 953.3 uS/m (Nasarawa Eggon). Average alkalinity value ranged between 4.3 mgL^{-1} (Keana) and 46.67 mgL^{-1} (Nasarawa Eggon). Average nitrate value ranged from 0.28 mgL^{-1} (Nasarawa Eggon) to 0.98 mgL^{-1} (Keana). Average acidity value ranged from 4.48 mgL^{-1} (Keana) to 24 mgL^{-1} (Nasarawa Eggon). The chloride values for the samples fell between 1.23 mgL^{-1} (Keana) and 24.82 mgL^{-1} (Nasarawa Eggon). Average phosphate value ranged from 0.04 mgL^{-1} (Nasarawa Eggon) to 3.15 mgL^{-1} (Keana). The average TDS ranged between 5.35 mgL^{-1} (Keana) and 476.67 mgL^{-1} (Nasarawa Eggon) in the samples. Average DO values fell between 2.87mgL^{-1} (Nasarawa Eggon) and 3.29 mgL^{-1} (Keana) while BOD ranged from 0.001 mgL^{-1} (Nasarawa Eggon) to 2.56 mgL^{-1} (Keana).

Table 1: Physicochemical parameters of the water samples from Keana

Parameter	WW	Bo.	St.	Mean	SD	CV%	WHO
pH	7.70	8.16	7.35	7.74	0.41	5.31	6.5-8.5
Conductivity (µS/cm)	4.48	4.56	3.94	4.33	0.34	7.85	1000
Alkalinity (mgL^{-1})	4.52	4.45	4.06	4.34	0.27	6.22	-
Nitrate (mgL^{-1})	0.84	1.16	0.95	0.98	0.16	16.33	50
Acidity (mgL^{-1})	4.32	4.61	4.50	4.48	0.15	3.35	-
Chloride (mgL^{-1})	1.20	1.29	1.20	1.23	0.52	20.33	250
Phosphate (mgL^{-1})	2.94	3.16	3.31	3.15	0.17	6.03	6.5
TDS (mgL^{-1})	4.64	5.31	6.11	5.35	0.74	13.83	500
DO (mgL^{-1})	3.10	3.40	3.38	3.29	0.17	5.17	5
BOD (mgL^{-1})	2.24	2.30	3.14	2.56	0.50	19.53	5

WW = Well water, Bo. = Borehole, St. Stream, SD = Standard deviation, CV = Coefficient of variance WHO = World Health Organization

Table 2: Physicochemical parameters of the water samples from Nasarawa Eggon

Parameter	WW	Bo.	St.	Mean	SD	CV%	WHO
pH	5.70	5.70	5.80	5.73	0.06	0.01	6.5-8.5
Conductivity (µS/cm)	1760	510	590	953.3	699.74	0.73	1000
Alkalinity (mgL^{-1})	45.00	45.00	50.00	46.67	2.89	0.62	-
Nitrate (mgL^{-1})	0.19	0.28	0.38	0.28	1.16	4.14	50
Acidity (mgL^{-1})	12.00	24.00	36.00	24.00	10.83	0.45	-
Chloride (mgL^{-1})	7.09	14.18	28.36	24.82	10.83	0.44	250
Phosphate (mgL^{-1})	0.01	0.05	0.05	0.04	0.02	0.05	6.5
TDS (mgL^{-1})	880	255	295	476.7	349.9	0.73	500
DO (mgL^{-1})	2.20	4.20	2.20	2.867	1.16	0.04	5
BOD (mgL^{-1})	0.05	0.04	0.05	0.05	0.02	0.03	5

WW = Well water, Bo. = Borehole, St. Stream, SD = Standard deviation, CV = Coefficient of variance WHO = World Health Organization

The heavy metal concentrations that were evaluated in water from Keana and Nasarawa Eggon are presented in Tables 3 and 4. The parameters were compared with WHO standards for water as shown in Table 5. The concentration of Pb ranged between 0.10 ±0.39 to 0.39 ±0.09 mgL^{-1} (Keana) and 0.36 ±0.09 to 0.88 ±0.35 mgL^{-1} (Nasarawa Eggon). The concentration of Zn ranged between 0.15 ±0.02 to 0.58 ±0.11 mgL^{-1} (Keana) and 0.19 ±0.03 to 2.41 ±0.22 mgL^{-1} (Nasarawa Eggon). The concentration of Mn ranged between 0.21 ±0.05 to 0.77 ±0.07 mgL^{-1} (Keana) and 0.22 ±0.03 to 0.87 ±0.07 mgL^{-1} (Nasarawa Eggon). The concentration of Cr ranged between 0.11 ±0.001 to 0.20 ±0.01 mgL^{-1} (Keana) and 0.06 ±0.02 to 0.43 ±0.01 mgL^{-1} (Nasarawa Eggon).

Concentration of Ni ranged between 0.10 ±0.04 to 0.20 ±0.02 mgL^{-1} (Nasarawa Eggon) and 0.21 ±0.04 to 0.39 ±0.03 mgL^{-1} (Keana). The concentration of Fe ranged between 0.10 ±0.01 to 0.57 ±0.03 mgL^{-1} (Keana) and 0.12 ±0.01 to 0.23 ±0.02 mgL^{-1} (Nasarawa Eggon). The concentration of Cu ranged between 0.15 ±0.01 to 0.37 ±0.03 mgL^{-1} (Keana) and 0.12 ±0.01 to 0.23±0.02 mgL^{-1} (Nasarawa Eggon).

Table 3: Concentrations of heavy metals (mgL^{-1}) in water samples from Keana

Metal	WW	Bo.	St.	Mean	SD	CV %	WHO
Pb	0.10 ±0.39	0.31±0.06	0.39 ±0.09	0.27	0.15	0.56	0.05
Zn	0.19 ±0.02	0.15±0.03	0.58 ±0.11	0.31	0.24	0.77	5
Mn	0.77 ±0.07	0.44±0.04	0.21 ±0.05	0.47	0.28	0.23	0.3
Cr	0.19 ±0.00	0.11±0.00	0.20 ±0.01	0.17	0.27	0.06	0.5
Ni	0.21 ±0.04	0.24±0.03	0.39 ±0.03	0.28	0.09	0.32	0.07
Fe	0.10 ±0.01	0.57±0.03	0.15 ±0.03	0.27	0.27	0.96	0.3
Cu	0.37 ±0.03	0.20±0.02	0.15 ±0.01	0.24	0.24	0.50	1

WW = Well water, Bo. = Borehole, St. Stream, SD = Standard deviation, CV = Coefficient of variance WHO = World Health Organization

Table 4: Concentrations of heavy metals (mgL^{-1}) in water samples from Nasarawa Eggon

Metal	WW	Bo.	St.	Mean	SD	CV %	WHO
Pb	0.37 ±0.02	0.36 ±0.09	0.88 ±0.35	0.54	1.60	2.96	0.05
Zn	0.19 ±0.03	0.84 ±0.17	2.41 ±0.22	1.15	1.41	0.99	5
Mn	0.77 ±0.07	0.44 ±0.04	0.21 ±0.05	0.47	0.28	0.60	0.3
Cr	0.06 ±0.02	0.43 ±0.01	0.30 ±0.00	0.26	0.14	0.54	0.5
Ni	0.10 ±0.04	0.15 ±0.02	0.20 ±0.02	0.15	0.05	0.33	0.07
Fe	0.23 ±0.02	0.00 ±0.00	0.12 ±0.01	0.12	0.11	1.09	0.3
Cu	0.23 ±0.02	0.00 ±0.00	0.12 ±0.01	0.12	0.11	1.09	1

WW = Well water, Bo. = Borehole, St. Stream, SD = Standard deviation, CV = Coefficient of variance WHO = World Health Organization

The physicochemical analysis revealed variations in parameters such as pH, conductivity, alkalinity, nitrate, acidity, chloride, phosphate, total dissolved solids (TDS), dissolved oxygen (DO), and biochemical oxygen demand (BOD) between Keana and Nasarawa Eggon.

The pH of water is a crucial parameter that reflects its acidity or alkalinity, providing essential information about the hydrogen ion concentration in the water. Tables 1 and 2 showed that the pH values observed in the water samples play a significant role in determining water quality. The average pH in Keana (7.74) was notably higher than in Nasarawa Eggon (5.73), indicating differences in the acidity levels between the two locations. These pH values, although varying, were within the permissible limit of 6.5 to 8.5 as stipulated by the National Standard, ensuring that the water quality met regulatory guidelines. The pH value for Keana is within the accepted limit for WHO while that of Nassarawa Eggon is slightly below the recommended range of 6.5 to 8.5 (WHO, 2017). The study by Moises *et al.*, (2021) from Goreangab Dam in Namibia reported lower pH values (4.96) compared to Keana and Nasarawa Eggon. This difference shows the regional variations in water quality parameters. Moises *et al.* (2021) further emphasized the adverse effects of acidic water on human digestive and lymphatic systems, emphasizing the critical role of pH in biological and chemical processes within water bodies. Based on the WHO recommendation (pH range of 6.5 to 8.5) for safe drinking water, the slightly acidic pH values observed in Nasarawa Eggon could be attributed to human activities generating high levels of CO_2 and SO_2, leading to the formation of acidic water. Additionally, the saline nature of the area may contribute to the acidity levels observed. The study by (Bilewu *et al.*, 2022) in Oyo and Lagos states further highlighted seasonal variations in pH levels, with lower pH values recorded in June, possibly due to increased rainfall during that period (Bilewu *et al.*, 2022). Opaluwa *et al.*, (2020) in Doma local government of Nasarawa state recorded slightly acidic pH values for borehole and well water samples, linking the acidity to activities around underground water sources and the geological composition of the area. Eneji *et al.* (2011) reported a pH of 7.12 for River Benue in the Makurdi Metropolitan Area, emphasizing the importance of pH monitoring in different water bodies to ensure water quality and ecosystem health.

Electrical conductivity (EC) of water is a critical parameter influenced by temperature and indicative of water salinity (Yadav and Jamal, 2018). It measures the water's ability to conduct electric current, primarily dictated by ion concentration from dissolved salts and inorganic elements (Bilewu *et al.*, 2022). WHO, (2017) has set the permissible EC limit at 300 µS/cm. In the two sampling locations, conductivity ranged between 3.94 and 4.56 µS/cm in Keana and between 510 and 1760 µS/cm in Nasarawa Eggon. The water at Keana is below the limit and Nasarawa Eggon exceeds it significantly, indicating high ion presence. This can further alter the chemical composition of water within Nasarawa Eggon. Eneji *et al.* (2011) reported an EC of 86.85 µS/cm for River Benue, while Opaluwa *et al.* (2020) found EC values of 277.16 and 296.29 µS/cm for borehole and well water in Doma Local Government Area, Nasarawa State. Aremu *et al*. (2014) identified a consistent EC reading of 1.0 µs/cm for some drinking water sources in Okene Local Government Area, Kogi State, Nigeria. Bilewu *et al.*, (2022) observed EC fluctuations over two sampling months in various locations like Oyo and Lagos State. Aniyikaiye *et al.* (2019) emphasized the direct relationship between EC and total dissolved solids (TDS) concentration, highlighting EC's importance in assessing water quality and salinity levels.

Alkalinity in water serves as a critical indicator of its acid-neutralizing capacity, with various factors contributing to its levels in groundwater. Aniyikaiye *et al.* (2019) and Patil *et al.* (2012) have identified carbonates, bicarbonates, ammonia, iron oxide, and titanium dioxide as significant contributors to groundwater alkalinity. Additionally, the presence of excessive lime usage in wastewater treatment processes has been linked to elevated alkalinity levels (Aniyikaiye *et al.*, 2019). The alkalinity in Keana ranged from 4.06 to 4.52 mgL^{-1}, while in Nasarawa Eggon, it varied between 45 and 50 mgL^{-1}. According to Patil *et al.* (2012), the recommended threshold for alkalinity is 200 mgL^{-1}. However, in cases where alternative water sources are unavailable, alkalinity levels of up to 600 mgL^{-1} are deemed acceptable for drinking purposes, underscoring the importance of context-specific assessments.

Nitrate constitutes the final stage in the oxidation of nitrogenous compounds; it is therefore a measure of the original quality of organic matter which water is associated most with. The conversion to nitrates by oxidation in soil and water is achieved by nitrifying bacteria and can only occur in a well oxygenated environment. Due to the increased use of synthetic nitrogen fertilizers and livestock manure in intensive agriculture, vegetables and drinking water may contain higher concentrations of nitrate now than in the past were reported (Ishaleku *et al.*, 2024). Nitrates generally occur in trace amount in surface water supplies and may attain high levels in some ground water (Whitehead, 1990). Nitrate concentrations in Keana range from 0.84 to 1.16 mgL^{-1} and were higher than those in Nasarawa Eggon (0.19 to 0.38 mgL^{-1}). The WHO permissible level for nitrate (WHO 2017) is 50 mgL^{-1}.

The presence of nitrate in water serves as a crucial indicator of organic matter quality, with its formation primarily attributed to the oxidation of nitrogenous compounds by nitrifying bacteria in well-oxygenated environments. The intensified use of synthetic nitrogen fertilizers and livestock manure in agriculture has led to elevated nitrate concentrations in both vegetables and drinking water, compared to historical levels. While surface water typically contains trace amounts of nitrate, groundwater may exhibit higher levels (Ishaleku *et al.,* 2024). Additionally, nitrate contamination can occur in some groundwater due to leaching from natural vegetation. Nitrates have a direct reaction with hemoglobin in human blood, leading to the production of methemoglobin, which impairs the ability of blood cells to transport oxygen. This condition, known as methemoglobinemia or "blue baby" disease, is especially serious in infants under three months of age (Tukura *et al.*, 2013). Nitrate levels in water primarily result from microbial nitrification processes, with contributions from sewage discharge, industrial effluents, and agricultural runoff. Notably, these values are below the permissible limits set by regulatory bodies. In Keana and Nasarawa Eggon, nitrate concentrations ranged from 0.84 to 1.16 mgL^{-1}, surpassing those in Nasarawa Eggon (0.19 to 0.38 mgL^{-1}). The WHO's permissible nitrate level stands at 50 mgL^{-1}. Despite this, the nitrate levels in the studied areas are notably lower than those reported by Tukura *et al.* (2013) in 13 local government areas of Nasarawa state, including Keana and Nasarawa Eggon, which were still within acceptable limits. Furthermore, the values reported by Opaluwa *et al.* (2020) in Doma, Nasarawa State, were even lower, with mean values of 0.024 mg/dm^3 in borehole water and 0.01 mg/dm^3 in well water, indicating superior water quality.

Acidity is the quantitative capacity of a water or solution to neutralize an alkali. In layman's terms, that means pH is a measure of the acidity or basicity of an aqueous solution. Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic or alkaline. Acidity in water is caused due to mineral acids, free CO_2 and aluminum sulphate (Aremu *et al*., 2011). The sampling locations, acidity ranged between 4.32 and 4.61 mgL^{-1} in Keana and between 12 and 36 mgL^{-1} in Nasarawa Eggon. Nasarawa Eggon has the highest acidity content with mean value of 24 mgL^{-1}.

The findings of this study reveal significant variations in chloride content across the studied regions, with Nasarawa Eggon exhibiting the highest concentrations (7.09 – 28.36 mgL^{-1}) and Keana recording the lowest (1.2 – 1.29 mgL^{-1}) as detailed in Table 1 and 2. These concentrations are notably lower than those reported by previous studies (Tukura *et al.*, 2013; Adeyemi *et al.*, 2007; Aremu *et al.*, 2017), indicating potential fluctuations in chloride levels over time. Chloride is present in nearly all natural water with varying concentration, depending on the geochemical condition of the area (Aremu *et al.,* 2017). Chloride has been associated with pollution and the legal level is set at 250 mgL^{-1} by the WHO (2017). Despite its natural occurrence, elevated chloride levels have been linked to pollution, prompting regulatory bodies such as the WHO to set a legal limit of 250 mgL^{-1} (WHO, 2017). Exceeding this limit not only imparts a saline flavor to water but may also induce laxative effects in individuals unaccustomed to high chloride levels. Natural and anthropogenic sources of chloride in surface and groundwater include runoff, inorganic fertilizer use, landfill leachates, septic system effluents, industrial emissions, irrigation discharge, and animal feed (Khatri & Tyagi, 2015).

Phosphates in surface water mainly originate from sewage effluents which contain phosphate based synthetic detergents or from agricultural effluents including run-off from inorganic fertilizers, or from industrial effluents. Unpolluted ground water usually contains insignificant concentration of phosphate (Ahmed, 2002). The Phosphate concentrations in Keana range from 2.94 to 3.31 mgL^{-1} and were higher than those in Nasarawa Eggon (0.01 to 0.05 mgL^{-1}). The WHO permissible level for Phosphate (WHO, 2017) is 6.5 mgL^{-1}. Excessive presence of phosphate in conjunction with nitrates and potassium, causes algal blooms which result in the death of aquatic organisms (Aniyikaiye *et al.,* 2019). The elevated phosphate concentration in Keana suggests water source contamination from agricultural runoff, particularly from farms employing inorganic fertilizers. Addressing this contamination is crucial to mitigate adverse ecological impacts and ensure water quality sustainability.

Total dissolved solids (TDS) represent a comprehensive measure of the dissolved content within water, encompassing both inorganic salts and organic matter, as well as various dissolved substances (Aniyikaiye *et al.*, 2019). The sources of these substances are diverse, including natural sources, wastewater, municipal and agricultural runoff, and industrial effluents (Bernard & Ayeni, 2012). Our study focused on two distinct locations, Nasarawa Eggon and Keana, revealing notable disparities in TDS levels. Nasarawa Eggon exhibited the highest average TDS content at 476.67 mgL^{-1}, while Keana displayed the lowest at 5.35 mgL^{-1}. Interestingly, Aremu *et al.*, (2014) recorded relatively lower values during both dry and wet seasons, suggesting potential seasonal variations in TDS concentrations. Most importantly, all water samples collected from both locations remained below the World Health Organization's (WHO) prescribed limit of 500 mgL^{-1}, indicating compliance with international standards for safe drinking water. The impact of TDS on cellular dynamics is significant, with water influx causing cellular swelling and elevated TDS levels leading to cellular shrinkage. Additionally, TDS can influence the taste of water and is often associated with increased alkalinity or hardness (Singh *et al.*, 2017). Moreover, TDS serves as a reliable indicator of water mineralization, with higher levels correlating with increased biological and chemical oxygen demand. This, in turn, can lead to the depletion of dissolved oxygen levels in aquatic ecosystems, posing potential risks to aquatic life. The sources of TDS in drinking water are multifaceted, including natural sources, sewage, urban runoff, and industrial wastewater (Tukura *et al.*, 2013; Adeyemi *et al.*, 2007).

Dissolved oxygen (DO) refers to the quantity of oxygen gas present in a water body. All types of life, including species responsible for self-purification mechanisms in aquatic ecosystems, require oxygen (Ostroumov, 2017). DO stands as a paramount parameter in water quality assessment, offering a wealth of direct and indirect insights. Its concentration within a water body serves as a pivotal indicator, reflecting diverse ecological processes such as bacterial activity, photosynthesis rates, nutrient availability, and the occurrence of stratification, among others (Premlata, 2009). The mean concentration of DO in Keana (3.29 mgL^{-1}) and were higher than those in Nasarawa Eggon (2.87 mgL^{-1}). The DO in Keana is greater than the mean concentration reported for the dry season by Tukura *et al.* (2012) and that of Nasarawa Eggon is relatively lower. However, both are greater than the mean concentration of DO for rainy season (Tukura *et al.*, 2013). Both are also lower than those reported by Aremu *et al.* (2014). Edori & Nna (2018) reported 3.74 to 3.29 mgL^{-1} which is higher than the two locations in Nasarawa State. The WHO permissible level for DO (WHO, 2017) is 5 mgL^{-1}. Most concentrations across locations were higher than the permissible limit. DO levels in water reflects the physical and biological reactions that endure in water and is usually influenced by aquatic plants and plankton concentration (Islam & Huda, 2016). Its concentration fluctuates with temperature, pressure, and salinity, with solubility diminishing as temperature rises. Consequently, warmer surface waters require less dissolved oxygen to achieve full air saturation compared to cooler waters. In freshwater ecosystems like lakes, rivers, and streams, DO levels vary seasonally, spatially, and with water depth, generally decreasing with higher temperatures, salinity, and elevation (Afred *et al.*, 2023).

Dissolved oxygen (DO) is a crucial parameter in water quality assessment, representing the amount of oxygen gas present in a water body (Ostroumov, 2017). It plays a vital role in supporting various life forms, including those responsible for self-purification mechanisms in aquatic ecosystems. The concentration of DO in water bodies serves as a key indicator of ecological processes such as bacterial activity, photosynthesis rates, nutrient availability, and stratification (Premlata, 2009). In this study the mean concentrations of DO in Keana (3.29 mgL^{-1}) and Nasarawa Eggon (2.87 mgL^{-1}), it was found that the DO levels in Keana were higher than those in Nasarawa Eggon. These values were also compared to previous studies, where the DO levels in Keana were reported to be greater than those in the dry season by Tukura *et al.,* (2012), while the levels in Nasarawa Eggon were relatively lower. Both locations had higher DO levels compared to the rainy season reported by Tukura *et al.* (2013) but lower than those reported by Aremu *et al.,* (2014). The World Health Organization (WHO) sets a permissible level for DO at 5 mgL^{-1} (WHO, 2017). Most of the concentrations observed across the locations mentioned in the study exceeded this limit. The levels of DO in water are influenced by physical and biological reactions occurring in the water, with aquatic plants and plankton concentrations playing a significant role (Islam & Huda, 2016). Additionally, DO concentrations fluctuate with temperature, pressure, and salinity, with solubility decreasing as temperature rises. Warmer surface waters require less dissolved oxygen to reach full air saturation compared to cooler waters. In freshwater ecosystems like lakes, rivers, and streams, DO levels vary seasonally, spatially, and with water depth. Generally, DO levels decrease with higher temperatures, salinity, and elevation (Alfred *et al.*, 2023). Understanding the dynamics of dissolved oxygen in aquatic environments is crucial for assessing water quality and ecosystem health.

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen that is needed for stabilization of organic matter that are biodegradable through the action of aerobic microorganisms and the oxidation of certain inorganic materials (Tikariha & Sahu, 2014). It refers to the amount of oxygen required to decompose organic materials in water. In this study conducted in Keana and Nasarawa Eggon, the mean BOD values were reported as 2.56 and 0.05 mgL^{-1}, respectively (Tables 1 and 2). According to Clair *et al.* (2003), water bodies with BOD levels ranging from 2 to 8 mgL^{-1} are considered moderately polluted. The World Health Organization (WHO) recommends a BOD concentration of 4 mgL^{-1} as a standard for water quality. However, Edori and Nna (2018) reported a BOD value of 4.92 mgL^{-1}, which exceeds both the WHO recommendation and the values observed in the recent study. Edori and Nna (2018) highlighted that BOD serves as an indicator of water contamination by organic substances and can be influenced by various inorganic and organic materials present in water. While the WHO guideline for BOD in water is set at 4.0 mgL^{-1}, it is suggested that a lower concentration of 1.0 mgL^{-1} is more suitable for drinking water to ensure its safety. BOD values exceeding 5.0 mgL^{-1} raise concerns about the potability of water due to the potential presence of harmful bio-organisms (Edori & Nna, 2018).

The analysis of heavy metal concentrations in water samples from Nasarawa Eggon and Keana revealed varying levels of lead (Pb), zinc (Zn), manganese (Mn), chromium (Cr), nickel (Ni), iron (Fe), and copper (Cu). The presence of heavy metals in water sources is a significant concern due to their potential health impacts. The highest mean value of Pb, 0.54 mgL^{-1} was recorded in Nasarawa Eggon while Keana recorded the least mean value of 0.27 mgL^{-1}. Tukura *et al.* (2014) reported 0.04 and 0.02 mgL^{-1} of Pb for Keana and Nasarawa Eggon, respectively. Ogah (2020) recorded 0.506 which is relatively higher than that of Keana. Studies have shown that lead poisoning can pose a significant danger for those who continually depend on such water (Jonasson & Afshari, 2017). Higher lead concentrations were reported from an assessment of seven salt lakes in Romania where mean values of up to 6 mgL^{-1} were recorded for Lead in the salt lakes sampled in the study (Radulescu *et al.*, 2014). The highest mean value of Zn 1.15 mgL^{-1} was recorded in Nasarawa Eggon while

Keana recorded the least mean value of 0.31 mgL^{-1}. Tukura *et al.* (2014) reported 1.81 and 0.45 mgL^{-1} of Zn for Keana and Nasarawa Eggon, respectively. Ogah (2020) recorded the concentration of zinc in the water samples ranged from 1.510 to 2.828 mgL^{-1} with all the values below WHO limit for zinc which is 5.000 mgL^{-1}. Both Nasarawa Eggon and Keana recorded the highest mean value of Mn 0.47 mgL^{-1}. The concentration of Mn in the two locations exceeded 0.05 mgL^{-1} for drinking water as specified by WHO (2017). Tukura *et al.* (2014) reported 0.08 and 0.06 mgL-1 of Mn for Keana and Nasarawa Eggon respectively. Ogah (2020) recorded a range of 0.019 - 0.589 mgL^{-1} for Mn in Keana Salt Lake. The highest mean value of Cr, 0.26 mgL^{-1} was recorded in Nasarawa Eggon and Keana had recorded the least mean value of 0.17 mgL^{-1}. Tukura *et al.* (2014) reported 0.24 and 0.02 mgL^{-1} of Cr for Keana and Nasarawa Eggon, respectively. Chromium values ranged from 0.054 to 0.0630 mgL^{-1} both values are above the WHO limit for chromium which is 0.050 mgL^{-1} as reported by Ogah, (2020). The highest mean value of Ni 0.28 mgL^{-1} was recorded in Keana and the least mean value of 0.15 mgL^{-1} was recorded in Nasarawa Eggon. The mean concentrations values above the WHO permissible limit of 0.070 mgL^{-1}. Tukura *et al.* (2014) reported 0.02 mgL^{-1} of Ni for both Keana and Nasarawa Eggon. Ogah, (2020) mean concentration values of Nickel in the five water samples shows a range of 0.197 to 0.800 mgL^{-1}. The highest mean value of Fe, 0.27 mgL^{-1} was recorded in Keana and Nasarawa Eggon recorded the least mean value of 0.12 mgL^{-1}. Tukura *et al.* (2014) reported 0.89 and 0.20 mgL^{-1} for Keana and Nasarawa Eggon respectively. The mean values of iron are below the WHO limit of 0.300 mgL^{-1}. That of Ogah, (2020) were above the WHO limit. The highest mean value of Cu, 0.24 mgL^{-1} was recorded in Keana and Nasarawa Eggon recorded the least mean value of 0.12 mgL^{-1}. All the sampled locations had copper concentration levels below 1.000 mgL^{-1} which is the WHO limit. Tukura *et al.* (2014) reported 0.02 and 0.04 mgL^{-1} of Cu for Keana and Nasarawa Eggon respectively. Ogah (2020) reported higher mean values (0.04 – 0.716 mgL^{-1}) but are still below the WHO limit. While some essential metals like Cu and Zn play crucial roles in enzyme activity, exceeding permissible limits for these metals can still have adverse health effects (Aremu *et al*., 2005). All the metals analyzed from Keana and Nasarawa Eggon are within the permissible limit except for Pb and Ni whose values exceeded the WHO specifications (WHO, 20017). Furthermore, the levels of Pb, Cu, and Cr which were higher than the permitted limits set by the WHO (2017) and SON (2012), indicating that the people may be at risk for harmful effects from heavy metals.

CONCLUSION

The physicochemical and heavy metals parameters of some sources of drinking water in Keana and Nasarawa Eggon, Nasarawa State such as pH, conductivity, total dissolved solids, alkalinity, nitrates, acidity, chloride phosphate, DO, BOD, zinc, lead, nickel, iron, copper, manganese, and chromium were evaluated. The results showed that most of the parameters determined did not exceed the permissible limits as specified by the World Health Organization (WHO). From this study it can be deduced that the management of our waters through restrained and restricted dumping of contaminants into these water bodies will proffer solutions to poor quality of water which should be used for the purpose of consumption.

CONFLICT OF INTEREST

Authors have declared that there is no conflict of interest reported in this work.

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