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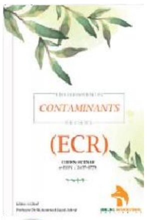

RESEARCH ARTICLE

EVALUATION OF PHYSICOCHEMICAL AND HEAVY METALS FROM WATER SOURCES IN UNIVERSITY OF BENIN COMMUNITY, EKENWAN CAMPUS, BENIN CITY, EDO STATE, NIGERIA

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ABSTRACT

Groundwater or borehole water is an important source of water in African towns and cities, and its quality is paramount to public health. The chemical and physical characteristics are of major importance in determining whether water is suitable for use. This study was aimed at determining the physicochemical properties and the heavy metal analysis of water sources in University of Benin, Ekenwan campus, Benin City, Edo State, Nigeria. The physicochemical properties and heavy metals components of the water was determined using standard methods of A.O.A.C Physicochemical parameters of water sources assessed were within FEPA acceptable limit except for the total suspended solid. The heavy metal result showed that zinc, copper and lead where within FEPA limits except iron and chromium which were above FEPA acceptable limit. Tested parameters such as pH, E.C., T.S.S, TUR, Hardness, Alkalinity, Chloride, Phosphate, Nitrate, Sulphate, Potassium, Iron, Copper, Lead and Cadmium were significantly different ($P<0.05$) in all the water samples while Calcium, Magnesium, Sodium and Chromium were not significantly different ($P>0.05$).

KEYWORDS

Groundwater, Physicochemical, Heavy metal, Borehole

1. INTRODUCTION

Water quality assessment is a crucial component of environmental and public health monitoring, especially in institutional settings like universities, where large populations rely on local water sources for daily consumption and sanitation. The University of Benin Ekenwan Campus, located in Edo State, Nigeria, depends on a combination of groundwater, boreholes, and possibly municipal supply for its water needs (Adegoke *et al.*, 2020). However, the physiochemical and heavy metal quality of these water sources remains underexplored and potentially vulnerable to contamination due to factors such as poor waste management, urban runoff, inadequate infrastructure, and aging plumbing systems. The World Health Organization emphasizes that access to safe and potable water is a fundamental human right and a determinant of public health (WHO, 2022). Water quality is typically assessed by examining physiochemical parameters, including pH, turbidity, conductivity, total dissolved solids (TDS), temperature, and concentrations of potentially harmful substances such as nitrates, heavy metals, and chlorides. These parameters provide a comprehensive understanding of the water's potability, aesthetic value, and potential health risks (Adegoke et al., 2020). Many Nigerian tertiary institutions suffer from poor sanitation and irregular water monitoring, resulting in unsafe drinking water. The situation is compounded in campuses like Ekenwan, which are located in peri-urban environments with limited governmental oversight and infrastructural investment (Egwari and Aboaba, 2002).

In addition, physiochemical parameters and heavy metal contamination play a critical role in determining water safety. Parameters such as pH and electrical conductivity influence not only the aesthetic properties of water but also its corrosiveness and interaction with plumbing systems (Oyedeji and Moninuola, 2011). High turbidity can shield microorganisms from disinfection, while elevated levels of nitrates or heavy metals such as lead and arsenic are associated with chronic health effects, including cancer, methemoglobinemia, and neurological damage (Govindarajan and Senthilnathan, 2014). The proximity of the Ekenwan Campus to residential and industrial zones raises the likelihood of leaching of contaminants from septic tanks, refuse dumps, and industrial effluents into the water table, particularly during the rainy season.

Water regulatory bodies such as the Nigerian Standards for Drinking Water Quality (NSDWQ) provide guidelines, but enforcement at local and institutional levels remains inconsistent. In the case of the University of Benin Ekenwan Campus, it is unclear whether current monitoring practices are adequate or aligned with national and international standards. There is a need for regular monitoring, testing protocols and support based interventions to improve the water system in university communities. This will help to sustain the health of those interacting with the university community every day.

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2. MATERIALS AND METHODS

2.1 Sampling Location

This study was carried in hostels at Ekenwan Campus, University of Benin, Benin City, Edo State. Edo State is located in the Southwestern part of Nigeria at longitude 6.6 °N and 5.9 °E. It is about 40 miles from the Gulf of Guinea.

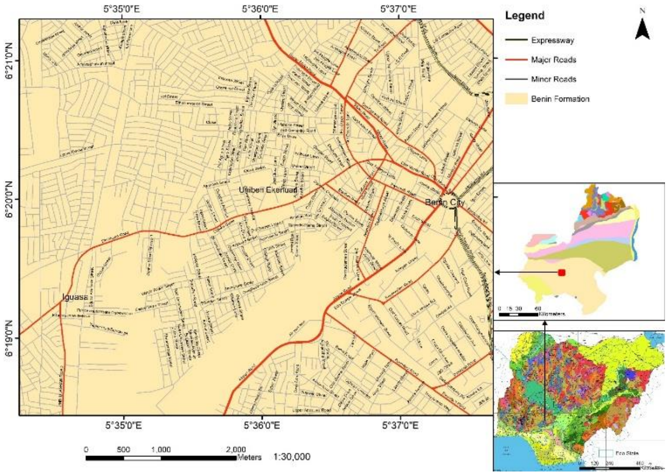

Figure 1: A map showing the entire environment of the studied area (Ekenwan campus, University of Benin, Benin City, Nigeria.

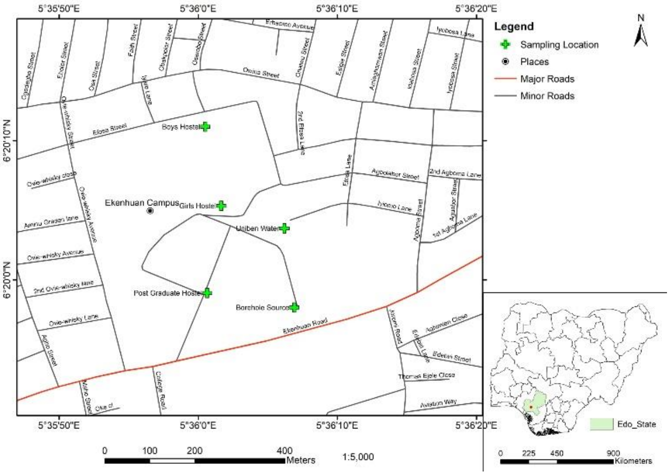

Figure 2: A map showing the sampling points in Ekenwan campus University of Benin, Benin City, Nigeria.

2.2 Sample collection

A total of 18 water samples (3 samples each in triplicate) were obtained from six (6) different. Borehole nuzzles were sterilized with 70 % acetone and allowed to run for five minutes before samples were collected into sterilized containers. All samples were collected between the hours of 7.00 am and 9. 00 am and carefully labelled and transported to the laboratory for analysis within 4 hours of collection (Ekhaise and Omavwoya, 2008; Thompson et al., 2012; Tsegahun et al., 2017).

2.3 Determination of physicochemical and heavy metals properties

Triplicate measurements of each physicochemical properties were made using the methods of (AOAC. 1990; WHO. 2017).

2.4 Data analysis

The results were analysed using Graph pad prism version 6. Data were presented as Mean = S.E.M, and statistical significance was calculated using one-way ANOVA.

3. RESULTS AND DISCUSSION

Physicochemical parameter of water samples from various hostels in University of Benin is shown in Table 4.1. pH values of the water samples ranged from 4.58±0.03 to 6.38±0.16, electrical conductivity (EC) ranged from 39.3±0.33 to 112.7±1.67 µs/cm, total dissolved solid ranged from 19.3±.033 to 56.0±1.00 mg/l, total suspended ranged from 19.3±0.33 to 56.0±1.00 mg/l, hardness ranged from 1.40±0.17 to 2.77±0.12 (mg/l), Alkalinity ranged from 0.83±0.05 to 1.58±0.19mg/l, Chloride ranged from 9.97±0.22 to 34.3±0.21mg/l, Phosphate ranged from 0.11±0.01 to 0.27±0.01mg/l, nitrate ranged from 0.08±0.00 to 0.66±0.01mg/l, Sulphate ranged from 0.20±0.01 to 0.38±0.02 mg/l, Calcium ranged from 0.04±0.01 to 0.06±0.00mg/l, Magnesium ranged from 3.56±0.47 to 5.54±0.46 mg/l).

Heavy Metal

pH, E.C., TDS, Hardness, Alkalinity, Chloride, Phosphate, Nitrate, Calcium, Magnesium, Sodium, Potassium, Zinc and Copper were within FEPA acceptable limit for drinking water while Iron and Chromium were above FEPA acceptable limit in drinking water respectively. Tested parameters such as pH, EC., TDS, S.S, T.S, TUR, Hardness, Alkalinity, Chloride, Phosphate, Nitrate, Sulphate, Potassium, Iron, Copper, Lead and Cadmium were significantly different (P<0.05) in all the water samples while Calcium, Magnesium, Sodium and Chromium were not significantly different (P>0.05) (Table 4.2).

Table 1: Physicochemical parameter of water samples from various hostels in University of Benin

Parameter	Source	GH	PG	Uniben	BH	NT	P value	FEPA limit
pH	4.64±0.07	4.58±0.03	5.26±0.16	5.97±0.05	4.68±0.05	6.38±0.16	0.00	6.5-8.5
E.C (µS/cm)	73.7±0.33	74.0±0.00	65.0±1.53	112.7±1.67	72.3±0.88	39.3±0.33	0.00	1000
TDS (mg/l)	37.0±0.00	37.0±0.00	32.3±0.88	56.0±1.00	35.7±0.67	19.3±.033	0.00	500
S.S (mg/l)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00	5
TSS (mg/l)	37.0±0.00	37.0±0.00	32.3±0.88	56.0±1.00	35.7±0.67	19.3±0.33	0.00	5
TUR (NTU)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00	1-5
Hardness (mg/l)	1.97±0.09	2.43±0.06	2.15±0.07	2.77±0.12	1.87±0.03	1.40±0.17	0.00	150
Alkalinity (mg/l)	0.90±0.04	1.38±0.07	1.15±0.03	1.58±0.19	0.97±0.03	0.83±0.05	0.00	100
Chloride (mg/l)	27.6±0.20	28.2±0.38	23.9±0.80	34.3±0.21	24.5±1.64	9.97±0.22	0.00	250
Phosphate (mg/l)	0.11±0.01	0.23±0.02	0.19±0.01	0.23±0.01	0.27±0.01	0.11±0.01	0.00	0.5
Nitrate (mg/l)	0.16±0.02	0.66±0.01	0.48±0.05	0.14±0.01	0.17±0.01	0.08±0.00	0.00	50
Sulphate (mg/l)	0.26±0.01	0.31±0.02	0.23±0.01	0.38±0.02	0.27±0.01	0.20±0.01	0.00	100
Calcium (mg/l)	0.04±0.01	0.04±0.01	0.06±0.00	0.05±0.01	0.04±0.00	0.05±0.00	0.24	75
Magnesium (mg/l)	5.54±0.46	3.56±0.47	3.85±0.11	5.45±0.14	5.09±0.49	4.77±0.69	0.09	50
Sodium (mg/l)	0.02±0.00	0.02±0.00	0.02±0.00	0.02±0.00	0.02±0.00	0.03±0.00	0.18	200
Potassium (mg/l)	0.57±0.03	0.61±0.03	0.41±0.03	0.43±0.03	0.42±0.06	0.34±0.03	0.00	10

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KEY

GH- Girls' hostel, PG- postgraduate hostel, NT-Notre Dame table water, B- Uniben table Water, BH- Boys' hostel,

EC- Electrical conductivity, T.S.S. – Total suspended solid, TUR- Turbidity, $P \geq 0.05$ = not significant, $P \leq 0.05$ = significant, FEPA = Federal Environmental Protection Agency

Table 2: Heavy metal parameter of water samples from various hostels in University of Benin

Parameter	Source	GH	PG	Uniben	BH	NT	P value	FEPA limit
Iron (mg/l)	1.06±0.05	0.76±0.01	0.64±0.02	0.98±0.03	0.56±0.01	0.69±0.02	0.00	0.3
Zinc (mg/l)	0.56±0.03	0.44±0.02	0.36±0.02	0.53±0.03	0.39±0.01	0.31±0.03	0.00	5.0
Copper (mg/l)	0.21±0.02	0.11±0.02	0.12±0.02	0.26±0.03	0.08±0.00	0.08±0.00	0.00	1.0
Lead (mg/l)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00	0.01
Cadmium (mg/l)	0.00±0.00	0.00±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)	0.23±0.10	0.25±0.02	0.23±0.10	0.25±0.02	0.10±0.04	0.19±0.01	0.27	0.05

KEY

GH - girls hostel, PG - postgraduate hostel, NT- Notre Dame table water, Uniben - Uniben table Water, BH- Boys hostel,

$P > 0.05$ = not significant, $P < 0.05$ = significant, FEPA = Federal Environmental Protection Agency

The physicochemical parameters of the water samples from the various hostels were compared with the Federal Environmental Protection Agency (FEPA) standards for drinking water. The result in Table 1 shows that the pH of all the water samples were within WHO pH limit of 6.5-8.5. This is also within the pH limit of 5.6 to 6.6 reported on the effects of storage on borehole water quality stored in plastic containers for prolong periods in Benin City (Atuanya et al., 2018). The analysis observed that pH values of 6.5- 8.0 are good for water intended for consumption (Abdullahi et al., 2013). The averagely low pH values of the water samples in this study may be due to environmental and commercial pollutants. This pH is undesirable, because it may have the potential of indirectly affecting the soil biota, as very low high pH can cause plant death (Dhanaji et al., 2016). It can also cause toxicity to plants through accumulation of the unionized ammonia on the soil. Water pH is also important because it affects other pollutants, in that, when it is very acidic, metals such as zinc, aluminum and copper are released causing them to accumulate in the food chain. Likewise, when it is more basic it causes the accumulation of the unionized ammonia ions (NH3) which are known to be very toxic to plants and animals (Jia et al., 2025). Long-term exposure to pH beyond the permissible limit affects the mucous membrane of cells (Josiah et al., 2014). The difference in pH values of the water samples may be attributed to failed water treatment process, anthropogenic activities such as sewage disposal and water pumping machines in the study area. The water from the borehole groundwater sources can also easily corrode the water piping due to the acidic nature of the water. Damaged metal pipes due to acidic pH values can also lead to esthetic problems, causing water to have a metallic or sour taste (Olaiya et al., 2016).

The result of electric conductivity of the water samples showed that it contained a permissible level of electrical conductivity as recommended by FEPA (1000 µS/cm) with UNIBEN water having the highest conductivity. As a study stated that specific conductivity of drinking water ranges from <25 to >500 µmhos/cm. Electrical conductivity is a useful indicator of mineralization and salinity or total salt in water sample (Adegboyega et al., 2015). Electrical conductivity is directly related to the concentration of ions in water and the higher the concentration of ions, the higher the conductivity. These conductive ions come from dissolved salts and inorganic materials (Oladipo and Adeboye, 2015). High electrical conductivity values are mostly associated with wastewater discharges from sewage and agricultural runoff, all of which are a factor at the study areas. In this study the high electrical conductivity levels recorded may be due to the high concentration of the conducting ions in soil as a result of elevated temperature and low pH (Gambo et al., 2015).

The total dissolved solids observed in this study were within the ideal range of 500 mg/l recommended by FEPA. The presence of total dissolved solid may be due to poor flushing and runoff and high evaporation during water processing. This result obtain in this study agrees with the study who reported that total dissolved solids of drinking water ranged from 148 – 198 mg/l of (Patel and Patel., 2020). Although total dissolved solids itself is not toxic, certain dissolved constituents in high concentrations can pose health risks. For instance, high levels of nitrate, fluoride, and heavy metals such as arsenic, lead, or cadmium contribute to elevated dissolved solids and can lead to serious health concerns (Kumar and Puri, 2017). Excessive sodium intake from drinking water may exacerbate hypertension, especially among vulnerable populations such as pregnant women or individuals with cardiovascular issues (Awasthi et al., 2021).

Total suspended solids are particles suspended in water that are not dissolved and can be trapped by a filter (Singh et al., 2020). Though total suspended solids are typically associated with aesthetic issues such as turbidity, it also has implications for human health, particularly when associated with microbial contamination and toxic substances (Raval et al., 2021). In the study area, the highest total suspended solid concentrations was found in the UNIBEN water. Total suspended solid in the water samples were above FEPA recommended limit. One of the primary sources of total suspended solids is when sediments are washed into water bodies (Khaiwal and Suresh, 2020). High total suspended solids levels provide a medium for microbial pathogens such as bacteria, viruses, and protozoa to attach to particulates, protecting them from disinfection during water treatment. This increases the risk of gastrointestinal diseases such as cholera, typhoid, and dysentery (Suthar and Singh, 2018). According to the WHO (2017), increased turbidity caused by high TSS interferes with chlorination and other disinfection processes

The turbidity is one of the important physical parameters for water quality, defining the presence of suspended solids in water and causes the muddy or turbid appearance of water body (Dauda et al., 2016). In the present study area, the turbidity level was within limits. All the samples analyzed were found within the limits prescribed by FEPA. This indicates that there were no presence of inorganic particulate matter and non-soluble metal oxides. The consumption of high turbid water may cause a health risk, as excessive turbidity can protect pathogenic microorganisms from effects of disinfectants (Olaiya et al., 2016; Dauda et al., 2016). Alkalinity is an important parameter of water quality whether it is to be used for domestic, industrial or agricultural purposes. Alkalinity of the water is the property attributed to the presence of alkaline earths. It is the property of water by which it prevents lather formation with soap and increases the boiling point of water (Allamin et al., 2015). The hardness of drinking water in the study area were within FEPA acceptable limit. The hardness may cause encrustation on water supply distribution systems. Long-term consumption of extremely hard water might lead to an increased incidence of urolithiasis, anencephaly, prenatal mortality, some types of cancer and cardiovascular disorders (Arouna and Dabbert, 2010).

Mineral components detected in the drinking water chloride, phosphate, nitrate, sulphate, calcium, magnesium, sodium and potassium where were all within FEPA permissible limit of drinking water. This result is in agreement with the studies of who assessed the physical and chemical parameters in drinking water samples of different places in Kadegaon Tahsil (Dhanaji et al., 2016). In their studies, they stated that borehole water contained sulphate, phosphate, nitrate, manganese and potassium and were within FEPA maximum permissible limit respectively.

Sulfate occurs naturally in water as a result of leaching from gypsum and other common minerals. Discharge of industrial wastes and domestic sewage tends to increase its concentration (WHO, 2011). In the study area, the sulfate concentration in borehole water from all the locations was found to be within FEPA drinking water regulation. Sulphate are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in groundwater and are from natural sources (Coria et al., 2007). In general, the average daily intake of sulfate from drinking-water, air and food is approximately 500 mg, food being the major source. However, in areas with drinking-water supplies containing high levels of sulfate, drinking-water may constitute the principal source of intake (WHO, 2004).

Phosphate may occur in groundwater as a result of domestic sewage, detergents and agricultural effluents with fertilizers (Helmut et al., 2011). Normally, groundwater contains only a minimum phosphorus level because of the low solubility of native phosphate minerals and the ability of soils to retain phosphate (Kundu et al., 2015). In the study area, the phosphate concentration were within the FEPA prescribed limit. The result of nitrate concentration obtained in this research work were within the maximum permissible limit of 50mg/l stated by FEPA for drinking water. The presence of nitrate could be as a result of the actions of algae through nitrogen fixation and water plants. However, these findings corroborate the findings as a study reported nitrate value of between 2.21 mg/l and 4.91 mg/l of (Manassaram et al., 2021). The research of observed that nitrate in drinking water is primarily a result of agricultural runoff, sewage discharge, and industrial effluents (Ward et al., 2018). High nitrate value concentration causes algal bloom while nitrate deprivation leads to increased lipid content in algae and in turn affect the water ecosystem. The study reported that nitrite prevents the blood cells from absorbing oxygen from water (Gomez et al., 2020). Nitrate can be endogenously reduced to nitrite, which reacts with amines and amides to form N-nitroso compounds, known carcinogens associated with gastric, esophageal, and colorectal cancers (Temkin et al., 2019). The concentration of calcium, magnesium, sodium and potassium which were within FEPA permissible limit observed in this study agrees with the findings of Singh et al. (2021) who reported borehole water samples contained calcium, magnesium, sodium and potassium which were within world health organization permissible limited. This study also agrees with the findings who reported that calcium, magnesium and sodium detected in borehole water were within WHO permissible limit of (Grillo et al., 2019; Niazi et al., 2020; Olalekan et al., 2020).

The findings of this study is also supported by. The result in Table 2 shows that the study presented high concentrations of heavy metals such as iron and chromium while Zinc and Copper were within FEPA permissible limits for drinking water in all the water sampling site. This finding is supported by the report analysis who reported that the presence of iron in borehole water was commonly attributed to the weathering of iron-bearing rocks and minerals such as hematite and magnetite of (Olalekan et al., 2020). Although iron is a vital nutrient involved in haemoglobin formation and enzymatic processes, excessive intake through water may contribute to iron overload, especially in individuals with hemochromatosis or similar metabolic disorders (Sadeghi et al., 2021). Elevated iron concentrations can also foster the growth of iron bacteria, leading to biofouling and secondary microbial contamination, thus indirectly posing health risks. The high concentration of chromium in this study is supported by the findings researchers reported that chromium contamination in borehole water is often linked to industrial effluents, particularly from leather tanning, electroplating, and pigment manufacturing industries of (Singh et al., 2021). Cr^{6+} is a known carcinogen, with long-term exposure linked to lung cancer, liver damage, kidney failure, and skin ulcers (Griffith et al., 2018). Even low-level ingestion over time may contribute to DNA damage and oxidative stress, making it a significant concern in groundwater safety. Cr^{3+}, though essential in trace amounts, can also be harmful at elevated levels. Chromium can corrode metal pipes and affect the portability and taste of water. Long-term accumulation in soils and aquatic systems due to improper borehole discharge management can lead to ecological toxicity (Niazi et al., 2020).

The level of zinc observed in this study could be due to low source factors along the study sites. It could also be attributed to unfavourable soil pH at sampling sites because zinc tends to ionize well at pH of around 4 (Olalekan et al., 2020). This research reported that Zinc can enter borehole water through the weathering of zinc-containing minerals, corrosion of galvanized pipes, and leaching from industrial and domestic waste (Aminu et al., 2021). At appropriate levels, zinc is vital to human health. However, excessive ingestion (typically above 10–15 mg/L) can result in gastrointestinal distress such as nausea, vomiting, and abdominal cramps (Nayak et al., 2019). Chronic exposure to high levels may impair copper absorption, leading to anemia and immune dysfunction (Rahman et al., 2021). The presence of copper in the water sample is also supported by the findings of who reported that Acidic water and low mineral content can accelerate leaching of copper into groundwater systems (Niazi et al., 2020). While copper is a necessary micronutrient for enzymatic activity and iron metabolism, high levels can be toxic, especially in infants and individuals with Wilson’s disease, a genetic disorder of copper metabolism. Acute copper poisoning can cause vomiting, diarrhea, stomach cramps, and liver damage. Long-term ingestion of copper-contaminated water may result in liver and kidney dysfunction (Griffith et al., 2018).

4. CONCLUSION

Many Nigerian tertiary institutions suffer from poor sanitation and irregular water monitoring, resulting in unsafe drinking water. Water samples from University of Benin Ekenwan campus showed that most physicochemical parameters were within FEPA. The heavy metals results were within limits apart from Iron and Chromium. Therefore, it is imperative to treat the borehole water in the campus and monitor other sources of water to make sure they are within safe limits.

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