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Physicochemical Assessment of Treated Water Samples along major Distribution Lines within the University of Ilorin Campus

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Abstract

This research article presents a comprehensive physicochemical assessment of treated water samples collected from various distribution points within the University of Ilorin campus. The quality of water is vital for public health and the preservation of the environment, yet it is often compromised by contaminants from both natural and man-made sources. This study aimed to evaluate key physicochemical parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), biological oxygen demand (BOD), and chemical oxygen demand (COD), alongside trace metal concentrations using atomic absorption spectroscopy (AAS). Water samples were obtained monthly over three months from various sites, including laboratories and hostels, to identify any possible changes in water quality. The results indicated significant fluctuations in COD and trace metal levels, raising concerns about compliance with national and international water quality standards. The findings point out the need for consistent monitoring and effective management strategies to mitigate health risks linked with waterborne diseases. This research emphasizes the critical role of maintaining high-quality water to protect public health and preserve aquatic ecosystems, ultimately contributing to sustainable water resource management within the university and beyond.

Keywords: Electrical conductivity, total dissolved solids, public health, trace metals, contaminants.

1. Introduction

Water, which has minerals that are essential to aquatic life and the rest of the planet, including humans, is a necessity for life to exist on Earth. The most significant freshwater resources on the planet are lakes and surface water reservoirs, which offer a variety of advantages. They serve as habitats for aquatic life, particularly fish, and are utilized for irrigation and domestic reasons (Dodds and Whiles, 2020). They provide a substantial portion of the world's biological variation as well as essential protein. They are significant for people all around the world in terms of culture and aesthetics and provide significant social and economic advantages (Carpenter et al., 2021; Okoro et al., 2014).

Access to superior-quality water is fundamental to lessening the risk of illness and improving living conditions. Natural water accommodates many impurities that may have entered aquatic systems through a variety of processes, such as soil leaching, atmospheric aerosol

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particle dissolution, weathering of rocks and soils, and various human activities like mining, metal processing, and use (Liu and Xu, 2024). Industrialization, the application of fertilizers in agriculture, and the growing human population are extra factors contributing to environmental contamination (Okoro et al., 2014; Ma et al., 2022). The World Health Organization estimates that 1.5 billion people worldwide lack access to safe drinking water and that at least 5 million fatalities per year are attributed to waterborne infections (Chan et al., 2021). These staggering figures indicate the urgent need to address water quality troubles to safeguard public health. Given the significant impact on global health, the purity of water for consumption must be evaluated regularly. Regular monitoring and testing can help identify contaminants and pathogens that may be present in water supplies, allowing for timely interventions and the implementation of effective treatment strategies.

Water needs to be examined before it is used for consumption, domestic, agricultural, or industrial reasons. Numerous physicochemical characteristics are frequently used to achieve this, and they mostly rely on the water's intended use and the necessary levels of quality and purity (Wale and Girma, 2023). Analyzing the physical and chemical attributes of water provides valuable insights into the extent of pollution and its potential impact on aquatic environments. There are various kinds of chemical, biological, and physical contaminants in water. To ascertain the concentration of these pollutants in the water, many tests are necessary. Water should be tested for organic compounds, biological pollutants, and heavy/trace metals to ensure that it is of high quality (Abubakar and Sa'id, 2022). All of these tests must be passed for water to be deemed safe to drink, and it must also have the necessary level of minerals (Wale and Girma, 2023). Important indicators of water quality are its physicochemical characteristics, which influence its solubility and nutritional content. pH is one such parameter (Saalidong et al., 2022). Another crucial parameter, electrical conductivity, is influenced by temperature, presence, concentration, and mobility of ions (Ogbeide and Edene, 2023). Total dissolved solids indicate the overall concentration of dissolved substances in water. The levels of different ions, trace metals, and nutrients in the sediments and water are indicative of the severity of pollution and the possible effects on the environment (Onoyima et al., 2022).

Therefore, this research seeks to evaluate the quality of treated water distributed within the University of Ilorin campus, identify potential variations in water quality at different points of the distribution network, and compare with national and international water quality standards. There have been studies previously carried out on this location, however, there is the need for continuous monitoring of the water quality due to increasing demand for water from this location and for a renewed confidence in the suitability of water from this location for domestic use.

2. Materials and Methods

2.1 Overview of Sample Collection Stations Study Area

The University of Ilorin (Unilorin) is located in Ilorin, a residential, industrial, and agricultural city in Kwara State, Nigeria. Water samples were collected from various distribution points across the Unilorin campus. These distribution points included Zamfara Hostel, Abuja Hostel, Lagos Hostel, the University Clinic, the Industrial Chemistry Laboratory, the Chemistry Laboratory, and the Faculty of Arts. Each location is represented as S1, S2, S3, S4, S5, S6, and S7, respectively. These locations are characterized by various activities requiring regular use of water. The increased domestic activities occurring in these locations make it imperative that they receive a water supply that meets the stipulated standard for consumption and domestic use.

2.2 Sample Collection

Water samples were gathered from various locations using polyethylene bottles. Before collection, each bottle was thoroughly cleaned with hot detergent, rinsed with deionized water, soaked in 10% nitric acid (HNO_3) overnight, and then rinsed three times with deionized water. The pH of the water samples was measured on the same day to ensure accurate readings. Treated water samples were collected from these stations, and water quality parameters were monitored monthly in February, March, and April 2023.

2.3 Sampling Handling and Storage

Water samples were collected into cleaned polyethylene bottles after allowing the first flush of water from the faucet for at least 5 minutes. Two litres of water samples were taken, covered, and labelled according to the collection point. Samples for trace metal determination were stored in separate 1 L polyethylene bottles and preserved with 3 ml of 1:1 nitric acid (HNO_3) and hydrochloric acid (HCl) to prevent oxidation and precipitation of heavy metals. These samples were stored at 4℃ before analysis to minimize physicochemical changes.

2.4 Physicochemical Analysis

2.4.1 Determination of pH

The pH meter used was a multifunctional HANNA pH meter, purchased in Nigeria. The water samples' pH was measured by first dipping the electrode into a beaker containing distilled water with a pH of 7.2, then into the water samples. The pH readings were recorded.

2.4.2 Determination of Total Dissolved Solid (TDS)

A bench TDS meter was utilized in measuring the TDS of the water samples. The TDS values were obtained by immersing the pH meter's electrode into the water samples and setting it to TDS mode.

2.4.3 Determination of Electrical Conductivity (EC)

The electrical conductivities were determined using a Hanna EC meter. The electrode was dipped into each water sample, and after each reading, it was immersed in a beaker containing distilled water before taking the next reading.

2.4.4 Determination of Biological Oxygen Demand (BOD)

Twenty cubic centimetres (20 cm^3) of the water sample were pipetted into a BOD bottle. Then, 5 cm^3 of 10% manganese dichloride ($MnCl_2$) solution and 5 cm^3 of alkaline iodide solution (20% NaOH, 15% KI) were added to the pipetted water sample. The BOD bottle was covered with a glass stopper to prevent air bubbles from entering, and the mixture was agitated and inverted for several minutes until a brown, dirty colour appeared. Ten cubic centimeters (10 cm^3) of 25% HCl were added to the solution, which was then stoppered and mixed. The contents were transferred to a 500 cm^3 conical flask, and the liberated iodine was titrated with 0.05 M sodium thiosulfate using starch as the endpoint indicator. The initial dissolved oxygen (DO) was calculated using the following formula:

$$DO\ \left({}^{mg}/_{L}\right) = \frac{Titre\ value(cm^3) \times Molarity \times 8000}{Volume\ of\ sample\ (cm^3)} \quad (1)$$

Another set of samples (20 cm^3 each) were kept in an airtight black polythene bag for an additional 5 days. The same procedures were then carried out to obtain the 5-day dissolved oxygen (DO_5) value.

The biological oxygen demand was then calculated using:

$$BOD\ (mg/L) = DO_0 - DO_5 \quad (2)$$

where DO_0 is the initial dissolved oxygen and DO_5 is the 5-day dissolved oxygen.

2.4.5 Determination of Chemical Oxygen Demand (COD)
Distilled water (10 cm^3) was transferred into a 250 cm^3 conical flask. To this, 10 cm^3 of 25% sulfuric acid (H_2SO_4) and 20 cm^3 of 0.01 M potassium permanganate ($KMnO_4$) were added. The mixture was heated in a boiling water bath for 30 minutes, allowed to cool, and then 10 cm^3 of 10% potassium iodide (KI) solution was introduced. The liberated iodine was titrated with 0.05 M sodium thiosulfate ($Na_2S_2O_3$), using two drops of starch as the endpoint indicator.

For each water sample, 100 cm^3 was pipetted into a 250 cm^3 conical flask, followed by the addition of 10 cm^3 of 25% sulfuric acid (H_2SO_4) and 20 cm^3 of 0.01 M $KMnO_4$. The samples were heated sequentially for 30 minutes, allowed to cool, and then 10 cm^3 of 10% KI solution was added. The solution was then titrated with 0.05 M $Na_2S_2O_3$, using starch as the endpoint indicator. The Chemical Oxygen Demand (COD) was calculated using the following formula:

$$COD\ (mg/L) = \frac{(A - B) \times M \times 40{,}000}{Volume\ of\ sample\ cm^3} \quad (3)$$

where A is the titre value of the distilled water, B is the titre value of the collected water sample, and M is the molarity of $KMnO_4$ used.

2.4.6 Determination of Trace Metals using AAS
The water samples were digested using the LEFORT Aqua Regia Digestion Method, a partial digestion technique utilizing a 3:1 mixture of nitric acid to hydrochloric acid. Before digestion, the samples were filtered to obtain a clear solution and shaken to ensure homogeneity. Fifty millilitres of each water sample were placed into a 250 ml conical flask, followed by the addition of 15 ml of HNO_3 and 5 ml of HCl. The solutions were then heated for 2 hours, allowed to cool, reconstituted to 50 ml with deionized water, and transferred into sample bottles. The same procedure was performed on a reagent blank containing deionized water. After digestion, the samples were analyzed in the laboratory using an atomic absorption spectrophotometer (Model: Buck Scientific 210VGP) to test for Copper (Cu), Lead (Pb), Zinc (Zn), Iron (Fe), and Manganese (Mn).

3. Result and Discussion
3.1 pH
The average pH values of the water samples ranged from 7.40 to 7.65 in February, 7.30 to 7.65 in March, and 7.40 to 7.65 in April, with the minimum observed at Lagos Hostel (S3) and the maximum at the Industrial Chemistry Laboratory (S5) and Faculty of Arts (S7), as shown in Figure 1. These values fall within the WHO standard range of 6.5 – 8.5 and are classified as neutral to slightly basic, suggesting that the water is appropriate for drinking and other domestic uses.

The results are consistent with those observed by Kannapiran (2019), who reported pH values ranging from 7.10 to 8.12, indicating a slightly alkaline condition. In contrast, Osinbajo and Majolagbe (2023) reported lower pH values of 5.66 to 6.87 during the dry season and 5.27 to

6.29 during the rainy season, suggesting higher acidity. Such low pH levels could be attributed to industrial pollution and can irritate the eyes and corrode pipes over time (Anseena-Beegom and Kumar, 2021).

3.2 Total Dissolved Solids (TDS)
The TDS values ranged from 68 mg/L to 179 mg/L in February, 65 mg/L to 154 mg/L in March, and 64 mg/L to 155 mg/L in April, with the lowest values recorded at the Chemistry Laboratory (S6) and the highest at the University Clinic (S1), as detailed in Figure 1. These results are consistent with Shirodkar (2019), who reported a range of 31 mg/L to 207 mg/L. The TDS levels are well within the WHO's recommended limit of 500 mg/L for drinking water and the maximum permissible limit of 1000 mg/L. Water with a TDS below 1000 mg/L is considered fresh and suitable for drinking and irrigation, as it does not significantly affect soil osmotic pressure. However, if TDS levels exceed the acceptable range, it could be harmful to the kidneys and unsuitable for use (Shirodkar, 2019).

3.3 Electrical conductivity (EC)
The electrical conductivity of the samples ranged from 147 µS/cm to 382 µS/cm in February, 128 µS/cm to 308 µS/cm in March, and 130 µS/cm to 310 µS/cm in April, with the lowest values recorded at the Chemistry Laboratory (S6) and the highest at Zamfara Hostel (S1), as shown in Figure 1. These values are well within the WHO limit of 1000 µS/cm, indicating that the total concentration of ionic solutes in the water is relatively low. 1

3.4 Biological Oxygen Demand (BOD)
Biological Oxygen Demand (BOD) indicates the amount of biological pollution present in water, estimating the quantity of biodegradable waste. In this study, BOD values ranged from 50 mg/L to 108 mg/L in February, 48 mg/L to 112 mg/L in March, and 42 mg/L to 134 mg/L in April, with the minimum observed in Lagos State (S3) and the maximum in the Faculty of Arts (S7). These values indicate high BOD levels. High BOD values occur when decaying plants, human or animal waste, or other organic compounds are introduced into the water. Low BOD values suggest less oxygen is being extracted from the water, indicating the water is purer and fit for consumption. Conversely, high BOD values indicate lower water quality, which can lead to undesirable taste, appearance, and odour, and leave less oxygen for oxygen-demanding species (Chapra *et al*, 2021).

The BOD standard for consumable/drinking water is 5 mg/L, treated wastewater is 30 mg/L, and polluted wastewater has a BOD value greater than 10 mg/L, according to the Central Pollution Control Board (CPCB). Figures 2, 3 and 4 show the BOD of treated water within the Unilorin campus in February, March, and April, respectively.

3.5 Chemical Oxygen Demand (COD)
The World Health Organization (WHO) recommends a COD limit of 10 mg/L for drinking water. The COD values measured at various sample sites ranged from 2.00 mg/L to 5.20 mg/L in February, 1.92 mg/L to 5.20 mg/L in March, and 2.80 mg/L to 4.00 mg/L in April, all within the regulatory body's limit.

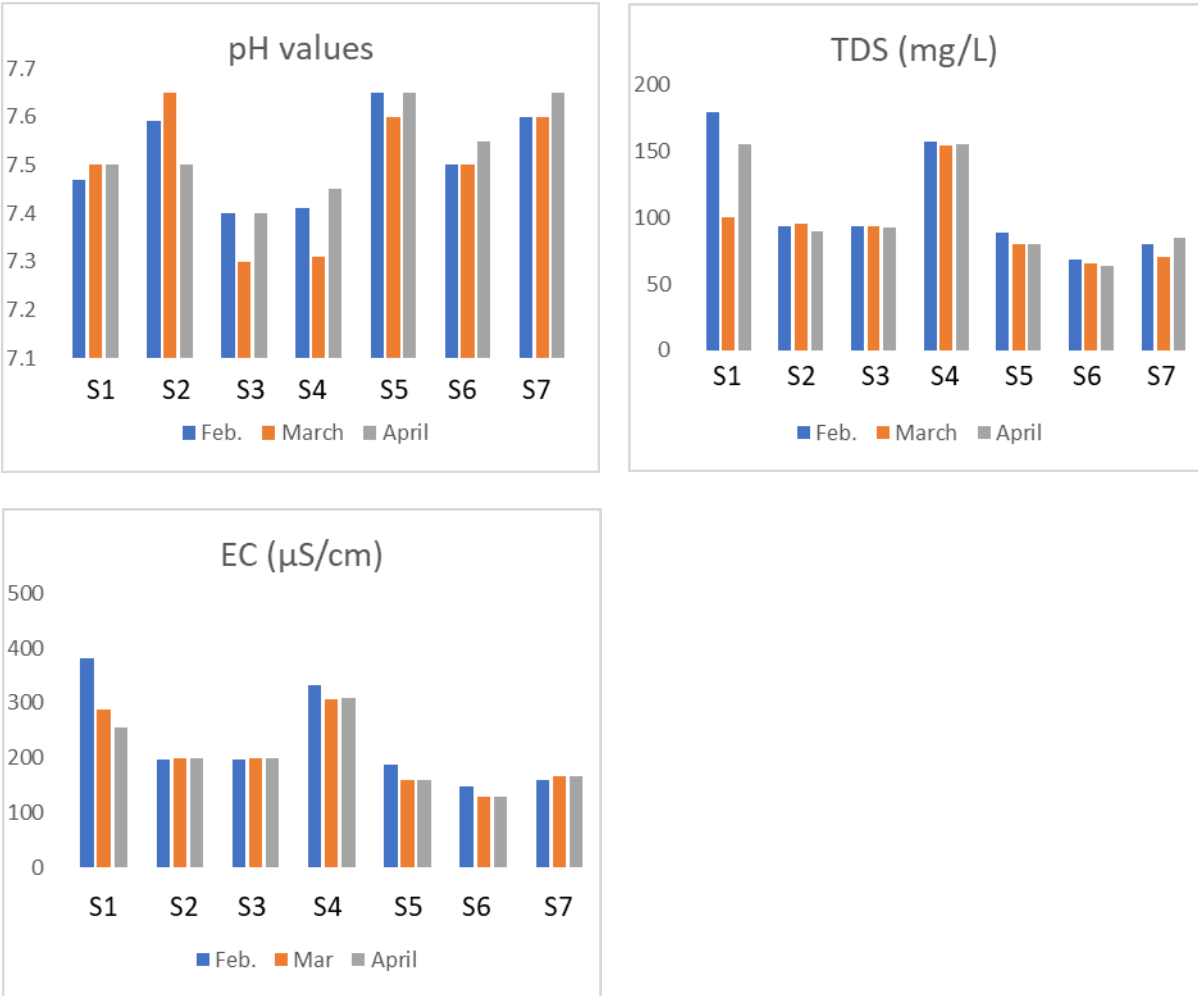

Figure 1: Results of pH, TDS and EC for February, March, and April 2023 (The unit of electrical conductivity is Siemens per meter (S/m) or micro-Siemens per centimeter (µS/cm) as used in this article)

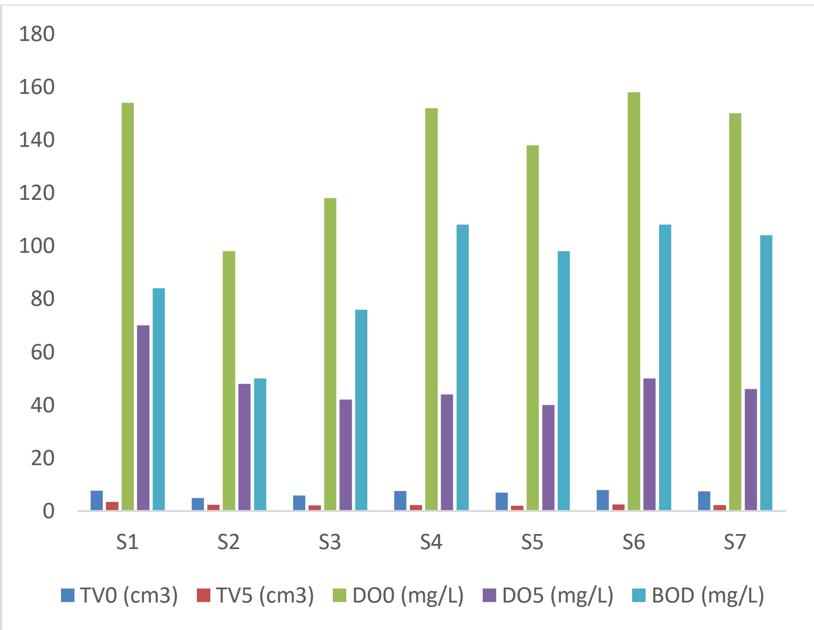

Figure 2: BOD Analysis Result for February, 2023
(TV_0 represents the initial titer value, while TV_5 represents the 5-day titer value)

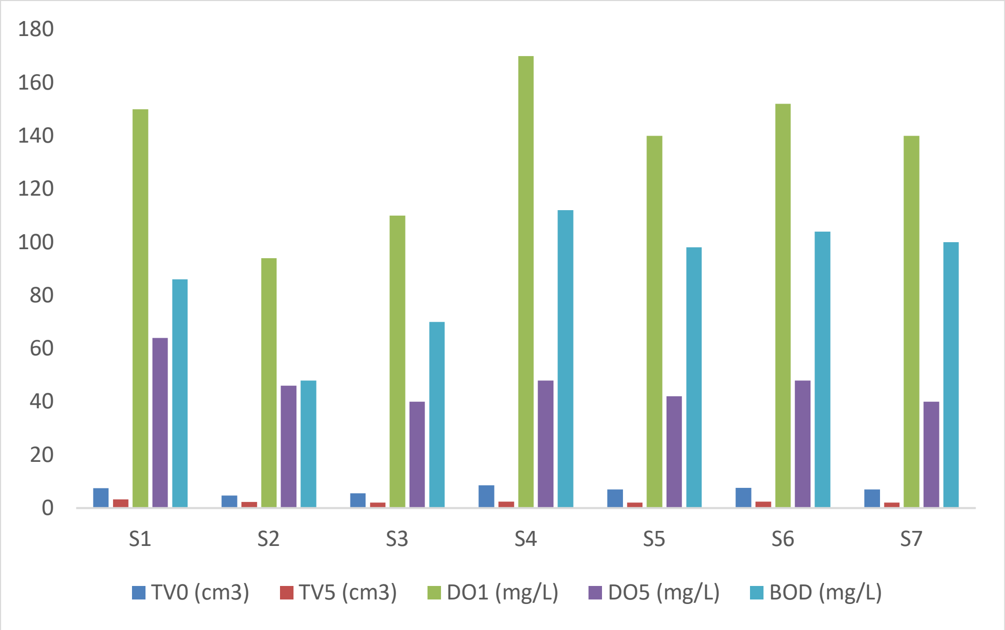

Figure 3: BOD Analysis Result for March, 2023

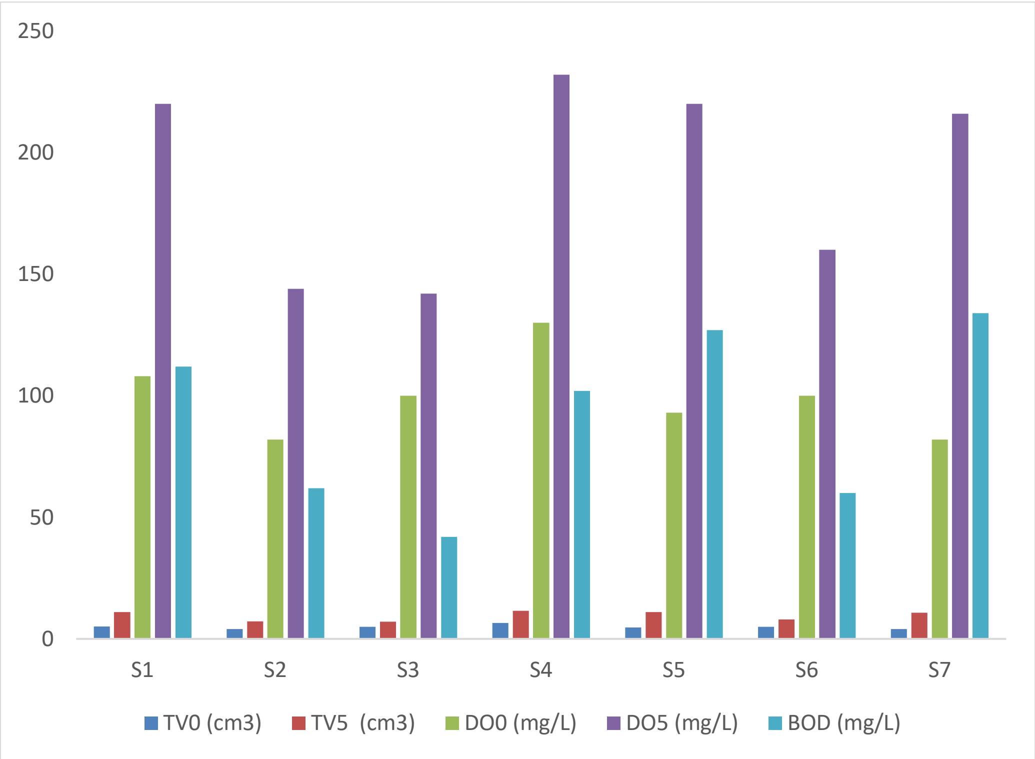

Figure 4: BOD Analysis Result for April, 2023

Exceeding the COD limit may result from high concentrations of decomposing plant matter, human waste, or industrial effluents. High COD values in water indicate the presence of more oxidizable organic material, which can lower the dissolved oxygen level and lead to anaerobic conditions, detrimental to aquatic life. Figure 5 shows the COD values of treated water within the Unilorin campus in February, March, and April.

3.6 Trace Metals

The presence of trace metals was analyzed using atomic absorption spectroscopy (AAS). The average concentrations of metals in water samples collected from various locations at the University of Ilorin in February, March, and April 2023 are detailed in Figures 6, 7, and 8, respectively.

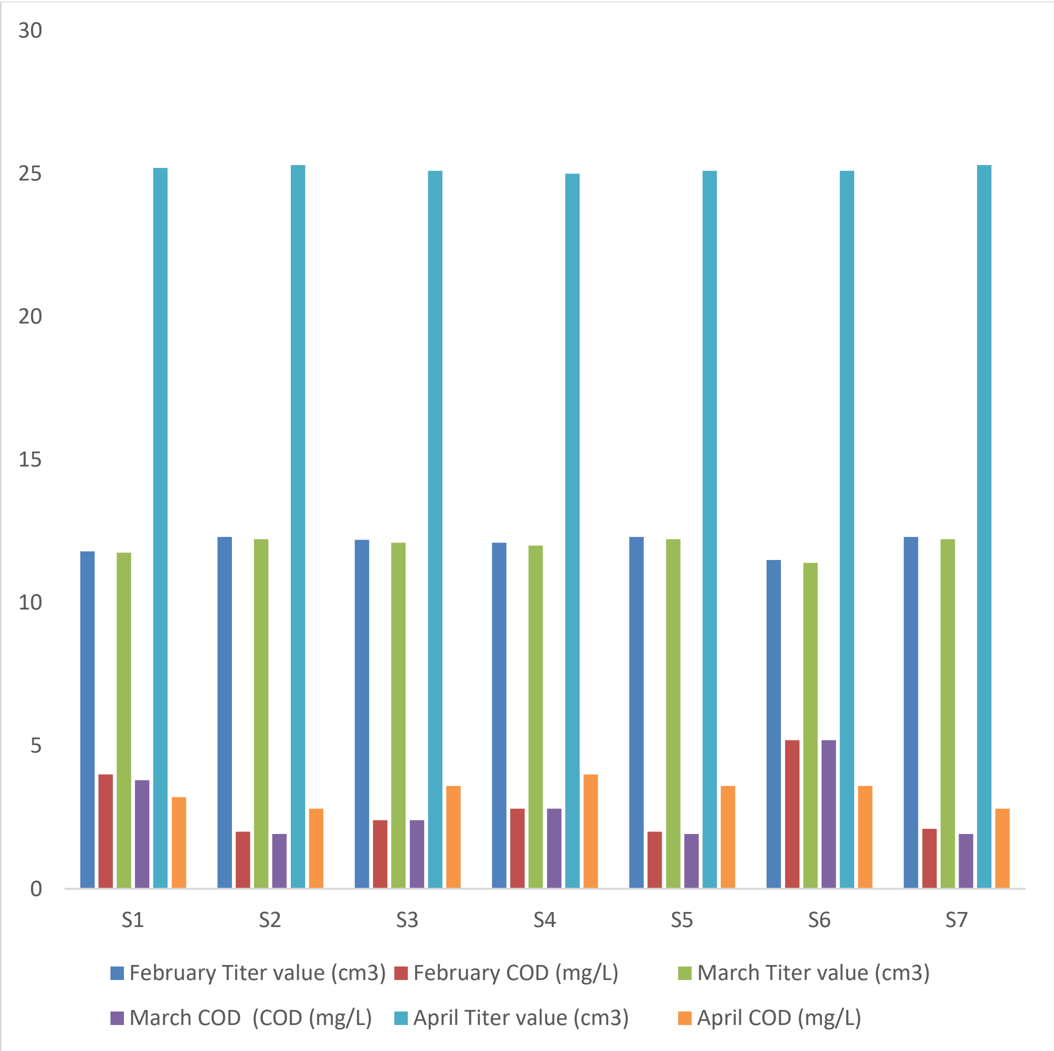

Figure 5: COD Analysis Result for February, March, and April 2023

In February, copper concentrations ranged from 0.009 mg/L to 0.121 mg/L, lead from 0.005 mg/L to 0.122 mg/L, zinc from 0.346 mg/L to 0.435 mg/L, iron from 0.200 mg/L to 3.075 mg/L, and manganese from 0.004 mg/L to 0.482 mg/L. In March, copper levels ranged from 0.008 mg/L to 0.178 mg/L, lead from 0.005 mg/L to 0.121 mg/L, zinc from 0.001 mg/L to 0.440 mg/L, iron from 0.220 mg/L to 3.000 mg/L, and manganese from 0.003 mg/L to 0.480 mg/L. In April, copper concentrations ranged from 0.021 mg/L to 0.203 mg/L, lead from 0.009 mg/L to 0.155 mg/L, zinc from 0.158 mg/L to 0.678 mg/L, iron from 0.267 mg/L to 3.150 g/L, and manganese from 0.015 mg/L to 0.268 mg/L.

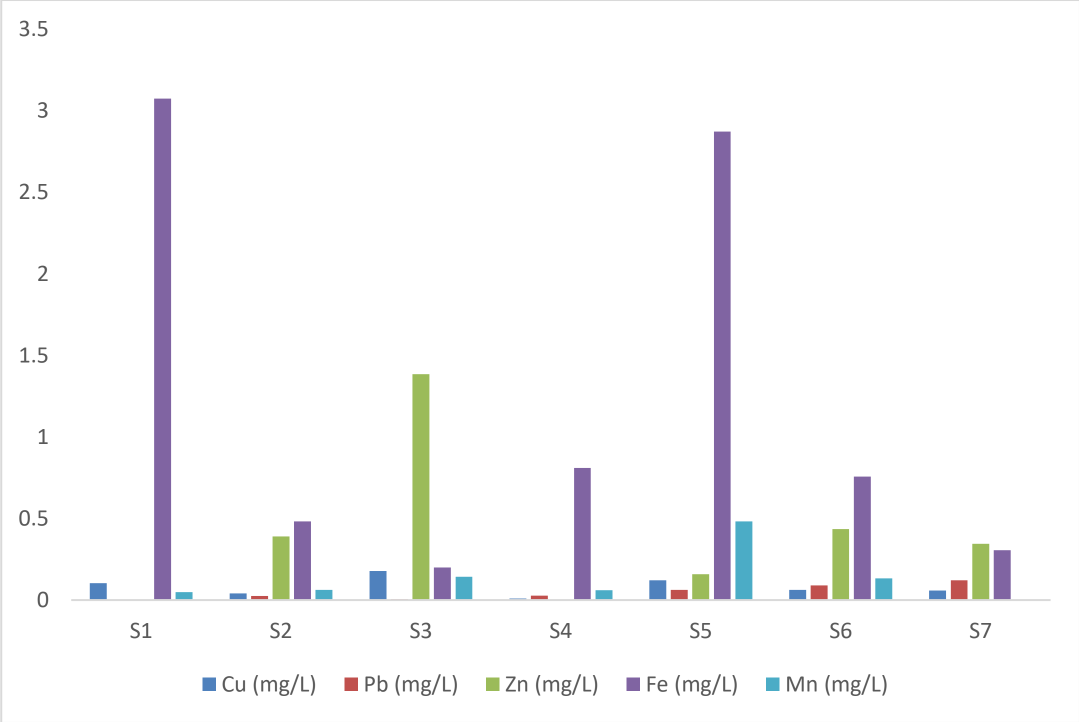

Figure 6: AAS Analysis Result for February, 2023

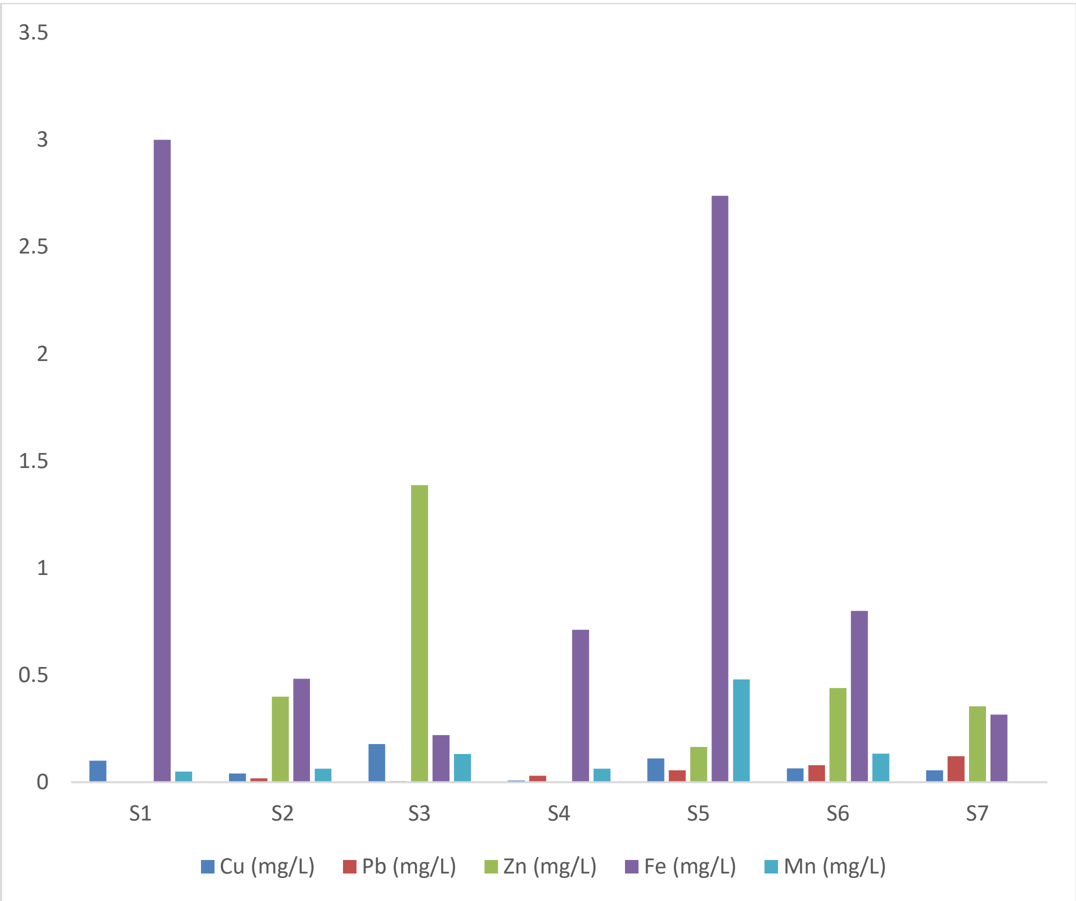

Figure 7: AAS Analysis Result for March, 2023

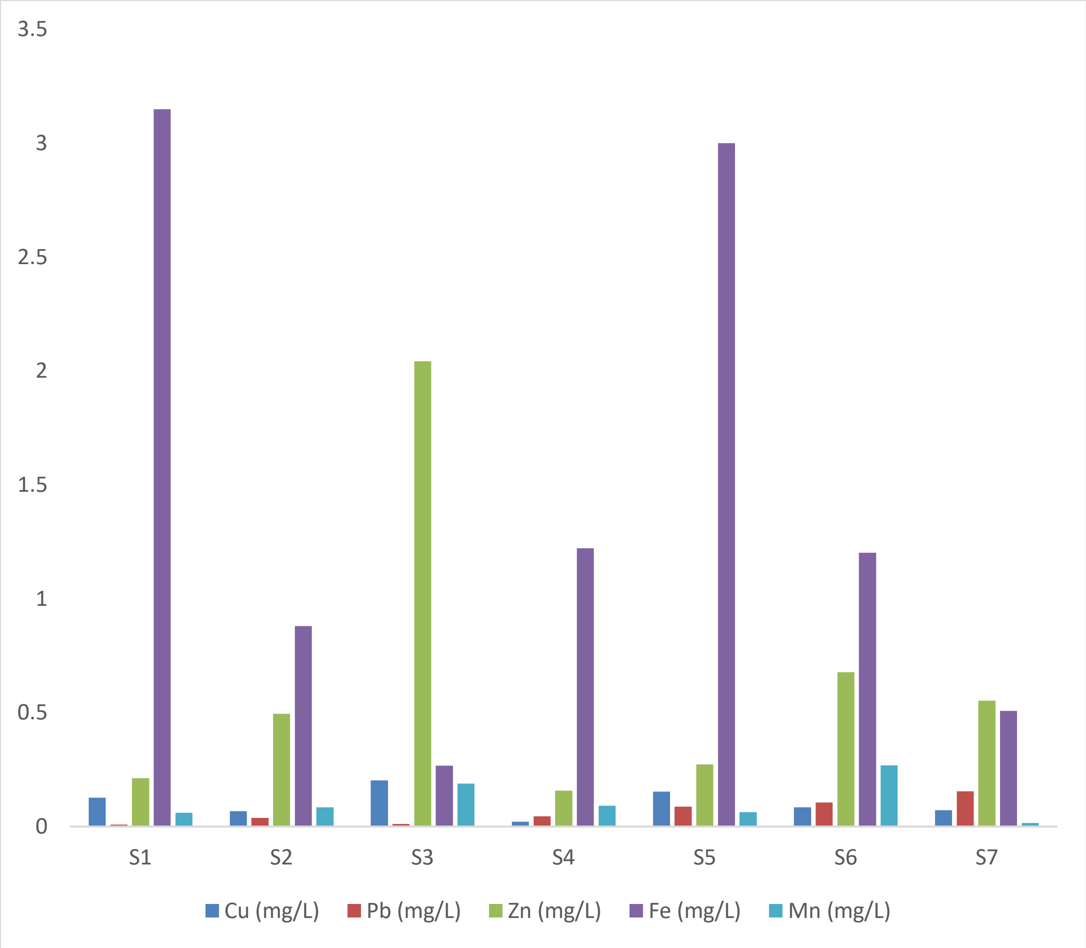

Figure 8: AAS Analysis Result for April, 2023

When compared to WHO standards (Table 1) for drinking water, it was observed that iron, manganese, and lead concentrations were above the standard limits, while the concentrations of copper and zinc were below the limits. Iron, an essential element, helps carry oxygen throughout the body. Although iron concentrations in drinking water seldom exceed 10 mg/L, even levels as low as 0.3 mg/L can result in a reddish-brown discolouration. During this research, tiny brownish substances were found in water samples collected from Zamfara and Abuja Hostels. The concentration of iron was high in all water samples collected, but the brownish particles were not present in all samples. This may be due to the presence of soluble ferrous iron, as iron generally occurs in two forms: soluble ferrous iron and insoluble ferric iron. As reported by WHO, rust formation in water pipes, caused by iron corrosion leads to the release of iron particles into the water, resulting in discoloured or rusty water from taps and plumbing systems According to Peninsula Water in 2022, excessive iron in drinking water can accumulate in organs such as the liver and pancreas, potentially leading to liver dysfunction and chronic conditions like diabetes mellitus (Peninsula Water Conditioning, 2022).

Table 1: WHO permissible limits of the analyzed trace metal ions

Trace metal ions	**WHO permissible limits (mg/L)**
Cu	1.50
Pb	0.01
Zn	5.00
Fe	0.30
Mn	0.40

Copper is an essential metal, vital for the micronutrients needed for the proper growth of plants, animals, and humans. High concentrations of copper can result in kidney and liver damage. Zinc is also essential for metabolic activities and overall well-being, but its toxicity can cause diarrhea. Similar to iron, zinc can cause deposits to build up in the distribution system. Manganese, an essential trace metal important for hair growth, was observed to be above the WHO permissible limit. While high concentrations of manganese do not typically pose a negative impact on human health, they can result in an undesirable appearance in the water. Lead, a toxic metal, can cause various diseases and health issues even in minute concentrations. Factors such as pH, temperature, and water hardness affect how much lead is dissolved in the plumbing system (WHO, 2019). Lead exposure can lead to mortality, poor fertility, hypertension, and unfavourable pregnancy outcomes (WHO, 2019). The levels of manganese, iron and lead observed in this study are attributed to both naturally occurring sources in groundwater and anthropogenic contamination due to the use of chemicals containing these metals for farming activities in the surrounding environment.

4. Conclusion

The physicochemical assessment of treated water samples from the University of Ilorin campus revealed significant variations in water quality, particularly concerning key parameters such as chemical oxygen demand (COD) and trace metal concentrations. The findings indicate that certain water samples exceeded national and international water quality standards, raising concerns about potential health risks associated with waterborne diseases. This emphasizes the urgent need for regular monitoring and assessment of water quality to safeguard public health and guarantee the safety of drinking water.

To address these issues, the university needs to implement a comprehensive water quality management plan. Establishing a routine monitoring program will allow for the continuous assessment of physicochemical parameters and trace metal concentrations in water samples from all distribution points. Also, public awareness campaigns should be launched to enlighten the university community about the significance of water quality and the health risks associated with contaminated water.

Investing in infrastructure improvements is also crucial; upgrading distribution networks and water treatment facilities can enhance the quality of treated water and reduce contamination risks. Furthermore, collaboration with local and national water quality regulatory agencies will ensure compliance with established standards and guidelines. Encouraging further research into innovative water treatment technologies and practices can provide effective solutions to address contamination issues.

By taking these steps, the University of Ilorin can significantly improve water quality, safeguard public health, and support the sustainable management of water resources.

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