Science Journal of Analytical Chemistry
2025, Vol. 13, No. 4, pp. 77–83
https://doi.org/10.11648/j.sjac.20251304.11

Research Article

Determination of Chemical Constituents and Trace Elements in Ground Drinking Water Around Chiro Town, West Hararghe, Ethiopia

Yoobsan Ejeta Amensisa[1,*], Berhanu Amenu Abdeta[2], Amanuel Ayale Gobosho[1], Mizbawu Kanea Gurmu[3]

[1]Department of Food Tech. and Process Eng., Oda Bultum University, Chiro, Ethiopia
[2]Department of Chemistry, Oda Bultum University, Chiro, Ethiopia
[3]Department of Environmental Engineering, Bule Hora University, West Guji Zone, Ethiopia

Abstract

This study evaluated the physicochemical quality of two drinking water samples collected from the Addis Ketema borewell and Arba Rakkatte, and designated as AK and AR, respectively, to evaluate their compliance with the World Health Organization (WHO) and Ethiopian Compulsory Standards (ECS) for potable water. Thirteen parameters were analyzed, including pH, total dissolved and suspended solids (TDS and TSS), chemical oxygen demand (COD), total hardness (TH), calcium (Ca), magnesium (Mg), alkalinity, and selected trace metals (Mn, Ni, Fe, and Zn). The results showed that the pH values (6.92–7.01) were within the permissible range, while TDS (470–560mg/L) and TSS (0mg/L) indicated good mineral balance. The COD values were zero, suggesting the absence of organic pollution. However, total hardness values (382.08–418.56mg/L) slightly exceeded the Ethiopian limit (300mg/L), primarily due to high calcium and magnesium concentrations. All trace metal concentrations (Mn, Ni, Fe, Zn) were well below permissible limits, indicating negligible contamination from metallic sources. Overall, both samples met the essential WHO and ECS requirements, except for hardness, which categorizes the water as *very hard* but not harmful to health. The findings confirm that the water is safe for drinking and household use; nevertheless, mild softening treatment is recommended to improve domestic suitability.

Keywords

Drinking Water Quality, Chemical Analysis, Heavy Metals, Chiro, Health, Hardness

1. Introduction

Safe drinking water is not supplementary but one of the vital requirements for life. Consuming contaminated water is the main source of illnesses [1-3]. In developing countries, including Ethiopia, there is a deficiency of access to safe drinking water from enhanced sources and to suitable sanitation services. According to the reported data from WHO 75% of all the diseases in developing countries arise from contaminated drinking water [4]. The problem associated with chemical constituents of drinking water arise mainly from their ability to cause adverse health effects. It is assumed that the most

[*]Corresponding author: yobsan.ejeta@obu.edu.et (Yoobsan Ejeta Amensisa)

Received: 15 October 2025; **Accepted:** 25 October 2025; **Published:** 19 December 2025

common hazards attributed to hardness, iron, sulfides, sodium chloride, alkalinity, acidity, and pathogens [5, 6].

Access to safe and clean drinking water is essential for human health and socioeconomic development. The quality of drinking water is influenced by both natural processes and anthropogenic activities such as industrial discharge, agricultural runoff, and improper waste disposal. The World Health Organization (WHO) and the Ethiopian Compulsory Standard (ECS) have established guideline values for key physicochemical parameters to ensure water safety and consumer acceptability. Evaluating these parameters helps to identify potential contamination, assess potability, and recommend appropriate treatment methods [7-9].

Among the critical indicators of water quality are pH**,** total dissolved solids (TDS)**,** total suspended solids (TSS)**,** chemical oxygen demand (COD)**,** total hardness (TH), and major *cations* and *anions* such as calcium, magnesium, and bicarbonates. The presence of trace metals like iron, manganese, nickel, and zinc also provides insight into possible industrial influence or corrosion within water distribution systems. High concentrations of these parameters can affect taste, cause scaling in domestic applications, or pose significant health risks if they exceed permissible limits [3, 10].

In Ethiopia, ensuring compliance with national and WHO drinking water standards remains a priority for public health and sustainable development. Therefore, this study was conducted to analyze and compare the physicochemical characteristics of two drinking water samples (AK and AR) against the WHO and Ethiopian guidelines [11, 12]. The assessment aimed to determine whether the water meets acceptable quality standards, identify any excess critical factors, and suggest practical recommendations for improvement where necessary.

2. Materials and Methods

2.1. Study Area and Sample Collection

Drinking water samples were collected from two bore wells, each serving different numbers of households in the study area. The samples were labeled as AK and AR, corresponding to their respective sources. Water samples were collected at room temperature using clean, high-density polyethylene bottles that had been pre-rinsed with the same water to avoid contamination. Immediately after collection, the samples were stored below 4 °C in iceboxes and transported to the JIJE Analytical Service Laboratory for analysis. All analyses were conducted following the methodologies described in “Standard Methods for the Examination of Water and Wastewater” [3].

Chiro town, the capital of the West Hararghe zone, is semi-arid with a latitude and longitude of 9°05′N 40°52′E and an average altitude of 1826 m above sea level. The town is located about 326 km from Addis Ababa, the capital of Ethiopia. The relative location of the Chiro district in west Hararghe, Oromia region, is shown in Figure 1 [2]. According to statistical data from Chiro municipality for 2022, approximately 69,793 people live in the town with an annual population change of about 5%. In this area, the municipal wastewater generated during different human activities, such as washing clothes and dishes, cleaning floors, septic tank leakages, etc., is disposed of in the environment without any treatment. According to some survey data, 41% of wastewater is stored in an open field, 35% is flown in an open ditch, 20% is released directly into a river across the town and only about 4% is collected in the septic tank.

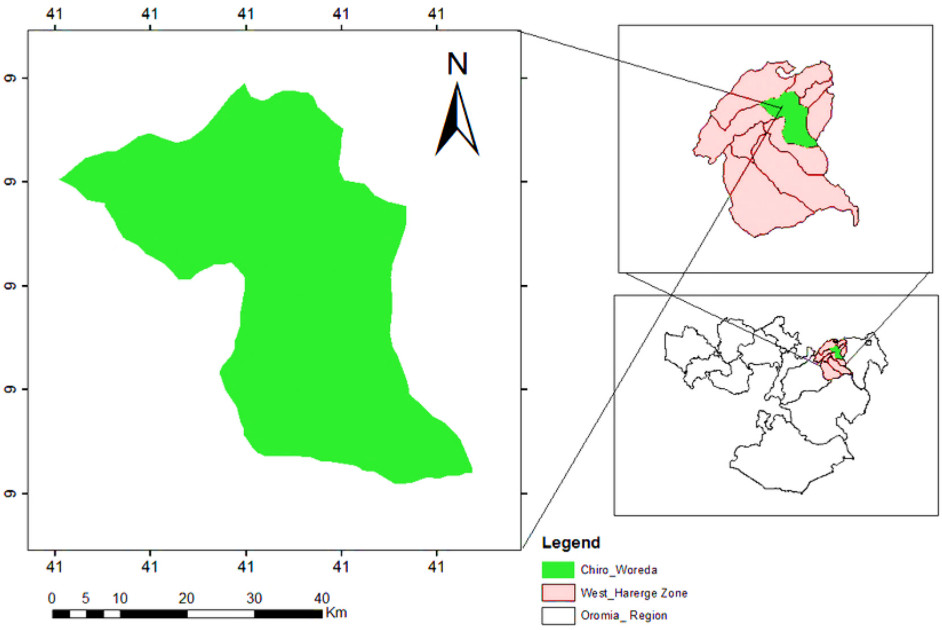

Figure 1. *Relative location of the study area.*

2.2. Instrument Calibration and Quality Control

Calibration for various chemical constituents was performed using low-level standard solutions prepared from laboratory-grade reagents. Instruments were standardized daily to ensure analytical accuracy. Duplicate samples, blanks, and calibration checks were routinely performed. Analytical precision was maintained within ±5% for all parameters, and results were expressed as the mean of triplicate measurements.

2.3. Physicochemical Analysis

2.3.1. pH and Electrical Conductivity (EC)

The pH and electrical conductivity (EC) of the samples were measured directly using potentiometric (pH meter) and conductometric (conductivity meter) instruments, respectively [13]. The pH meter was calibrated using buffer solutions of pH 4.0, 7.0, and 10.0 prior to each measurement, while the conductivity meter was standardized with a 0.01 M KCl solution.

2.3.2. Total Suspended Solids (TSS) and Total Dissolved Solids (TDS)

TSS and TDS were determined using the gravimetric method. For TSS determination, a known volume of the sample (100 mL) was filtered through a pre-weighed glass fiber filter paper, which was then dried at 103–105 ℃, cooled in a desiccator, and reweighed.

For TDS, the filtrate was evaporated and dried at 180 ℃ until a constant weight was achieved.

2.3.3. Chemical Oxygen Demand (COD)

COD was determined using the standard open reflux method. A known volume of sample was digested with potassium dichromate and concentrated sulfuric acid under reflux conditions. After digestion, the excess dichromate was titrated with ferrous ammonium sulfate in the presence of an indicator. The COD values were expressed inmg/L O2 [14].

2.3.4. Determination of Major Cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+})

The principal cations, calcium (Ca^{2+}) and magnesium (Mg^{2+}), were determined by EDTA titrimetric method using Eriochrome Black T, with the presence of indicators for total and calcium hardness, respectively. Magnesium concentration was obtained by difference.

Sodium (Na^{+}) and potassium (K^{+}) concentrations were measured using a flame photometer calibrated with appropriate standard solutions [15].

2.3.5. Determination of Major Anions (CO_3^{2-}, HCO_3^{-} , SO_4^{2-} , and Cl^{-})

Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^{-}) ions were determined by acid titration using standard HCl and phenolphthalein and methyl orange indicators to determine the phenolphthalein and total alkalinity endpoints, respectively. Sulfate (SO_4^{2-}) ions were analyzed using the turbidimetric method, where barium chloride ($BaCl_2$) was added to form barium sulfate turbidity, and the absorbance was measured spectrophotometrically. Chloride (Cl^{-}) was measured by argentometric titration using silver nitrate ($AgNO_3$) with potassium chromate (K_2CrO_4) as an indicator.

2.4. Data Interpretation

The physicochemical results obtained for samples AK and AR were compared with the World Health Organization [11, 16] and Ethiopian Compulsory Standards [12] for drinking water. Parameters exceeding the standard limits were identified and discussed to evaluate potential.

Table 1. *Classification of water based on hardness by Sawyer and McCarthy [13].*

Hardness as $CaCO_3$, mg/L	Water quality	Percentage
0-75	Soft	10.26
75-150	Moderately hard	33.33
150-300	Hard	28.21
>300	Very hard	28.21

3. Results and Discussion

Table 2*. Comparison of the experimental results of the chemical analysis of ground drinking water samples with international and national standards****.***

Sr. Nº	Quality Parameters	WHO standards	Ethiopian Compulsory Standard (*max. permissible limit*)	This study experimental results		Unit
				Sample ID: *AK*	Sample ID: *AR*	
	pH	6.5 – 8.5	6.5 – 8.5	6.92	7.01	Standard
	Total Suspended Solid (TSS)			0.00	0.00	
	Total Dissolved Solids (TDS)	500 – 1500	1000	560.00	470.00	
	Chemical Oxygen Demand (COD)			0.00	0.00	
	Total Hardness (TH as $CaCO_3$)	100 – 500	300	418.56	382.08	
	Magnesium (Mg)	30	50	44.06	41.99	
	Calcium (Ca)	75	75	82.32	46.08	mg/L
	Bicarbonate alkalinity (HCO_3^-)			381.6	327.6	
	Carbonate alkalinity (CO_3^{2-})			0.00	0.00	
	Magnesium (Mn)		0.5	0.02	0.00	
	Nickel (Ni)			0.00	0.00	
	Iron (Fe)	0.3 – 1.0	0.3	0.01	0.00	
	Zink (Zn)		5	0.08	0.01	

1) pH

The pH values of the two samples, AK (6.92) and AR (7.01), are within the acceptable range of 6.5–8.5 recommended by both the WHO and Ethiopian Compulsory Standard (ECS). This indicates that both water samples are neutral to slightly basic, suggesting good chemical stability and no significant acid–base imbalance. Water within this range is safe for consumption and prevents corrosion or scaling in pipelines [10].

2) Total Suspended Solids (TSS)

The TSS values for both samples were 0.00mg/L, indicating excellent clarity and the absence of particulate or turbidity-causing materials. Although WHO does not specify a limit for TSS, low or zero values are desirable for drinking water as they enhance aesthetic quality and reduce the risk of microbial growth [17].

3) Total Dissolved Solids (TDS)

The measured TDS values were 560mg/L (AK) and 470mg/L (AR), as shown in Figure 2b. Both values are below the Ethiopian maximum permissible limit (1000mg/L) and within the WHO recommended range (500–1500mg/L). These findings indicate that the water is fresh and palatable. The slightly lower TDS in sample AR suggests lower mineralization and better taste quality.

4) Chemical Oxygen Demand (COD)

The COD values for both samples were 0.00mg/L, showing that organic pollutants are absent. This reflects the high chemical purity of the water and confirms that the source is not affected by organic waste or industrial effluents.

5) Total Hardness (TH as $CaCO_3$)

As it can be seen from Figure 2a, the total hardness values were 418.56mg/L (AK) and 382.08mg/L (AR)**,** exceeding the ECS limit of 300mg/L and slightly above the WHO guideline range (100–500mg/L). This classifies both samples as *very hard water*, primarily due to the elevated calcium and magnesium concentrations. Although hardness is not a direct health risk, it affects soap performance, causes scaling in boilers, and may influence taste.

6) Magnesium (Mg)

Magnesium levels were 44.06mg/L (AK) and 41.99mg/L (AR), within the Ethiopian permissible limit of 50mg/L and slightly above the WHO recommendation of 30mg/L. These concentrations are acceptable for drinking water and contribute to the total hardness. Raised magnesium is typical in groundwater from mineral-rich geological formations [18].

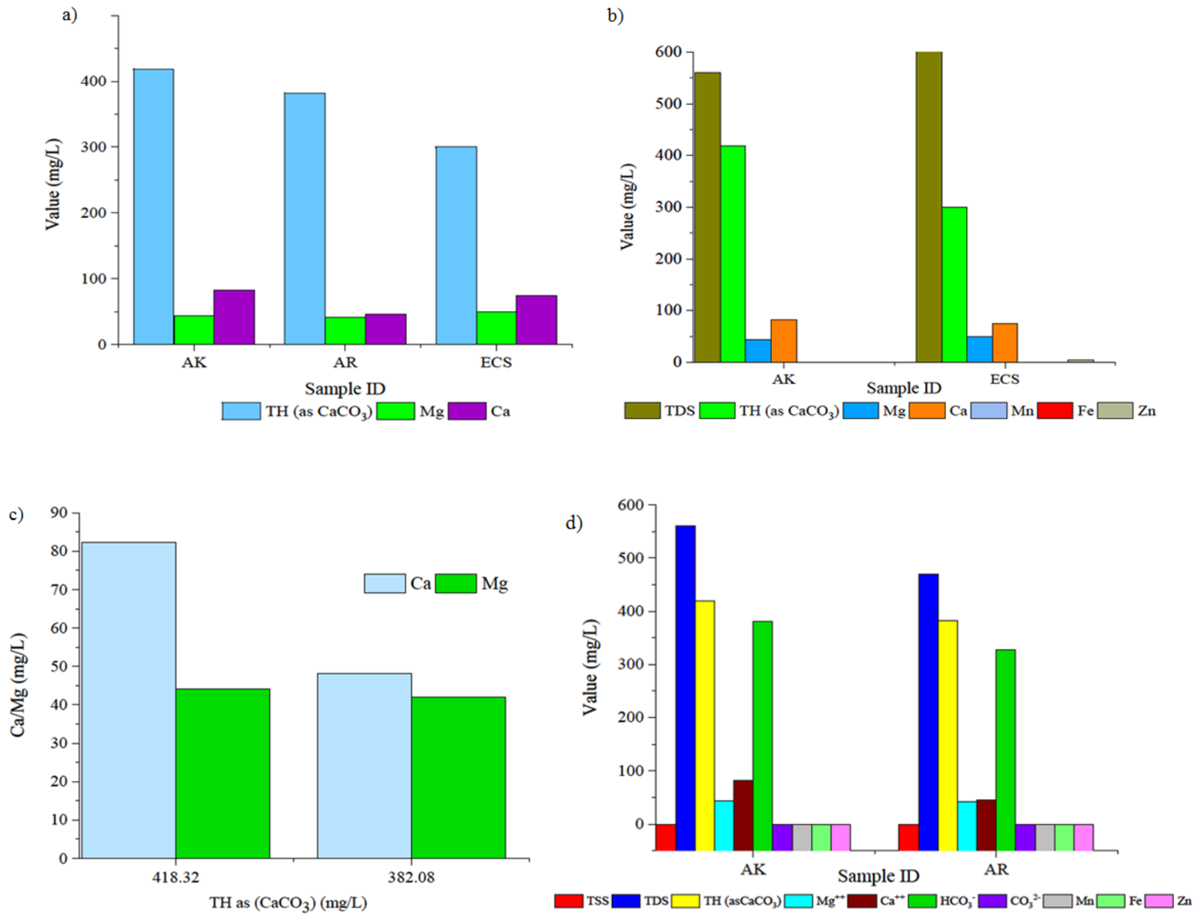

Figure 2. *Experimental results for AK and AR samples.*

7) Calcium (Ca)

The calcium concentration in sample AK (82.32mg/L) slightly exceeds the ECS and WHO limit (75mg/L), while sample AR (46.08mg/L) remains within the acceptable range as presented in Figure 2c. High calcium contributes significantly to the hardness observed in AK. Despite this, the calcium level is not harmful and may even provide dietary benefits; however, excessive concentrations can cause scaling and taste alteration [4].

8) Bicarbonate Alkalinity (HCO_3^-)

The bicarbonate alkalinity values were 381.6mg/L (AK) and 327.6mg/L (AR). Although not directly regulated by WHO, these values indicate moderate alkalinity. Such levels provide good buffering capacity to resist sudden pH changes but may cause a slightly bitter taste if too high. The high bicarbonate content correlates with the high hardness values observed.

9) Carbonate Alkalinity (CO_3^{2-})

Both samples recorded 0.00mg/L carbonate alkalinity, implying that alkalinity originates mainly from bicarbonate ions. This composition is typical for groundwater or treated water in equilibrium with atmospheric CO_2, helping maintain a stable near-neutral pH.

10) Manganese (Mn)

The manganese content was 0.00mg/L in both samples, significantly below the maximum limit of 0.5mg/L (see Figure 2d). This indicates that the water is free from manganese contamination, which could otherwise cause black stains, metallic taste, or neurological issues with chronic exposure.

11) Nickel (Ni)

Nickel was not detected (0.00mg/L) in both samples. The absence of nickel indicates no industrial contamination or leaching from plumbing materials. This is desirable, as nickel can be toxic at trace concentrations.

12) Iron (Fe)

The iron concentration was 0.01mg/L in both samples, much lower than the permissible limits (0.3mg/L ECS**,** 0.3–1.0mg/L WHO). This demonstrates excellent quality, with no metallic taste or reddish staining potential. The low iron concentration also implies minimal corrosion of pipes and fittings.

13) Zinc (Zn)

Zinc concentrations were 0.08mg/L (AK) and 0.01mg/L (AR), far below the ECS limit of 5mg/L. These trace amounts are beneficial for human health and improve taste slightly. Excess zinc, however, could cause an unpleasant metallic flavor; hence, the observed low values are ideal [4].

4. Conclusion

The overall analysis shows that both water samples comply with the WHO and Ethiopian Compulsory Standards for drinking water, except for total hardness, which slightly exceeds the permissible limit. The elevated hardness is due to high calcium and magnesium concentrations, yet it poses no immediate health risk. All other parameters – pH, TDS, COD, iron, manganese, nickel, and zinc are within safe limits, confirming that the water is chemically safe and of good quality for drinking purposes. However, mild softening treatment or mixing with softer water is recommended to reduce hardness and improve household utility performance.

Abbreviations

AK	Addis Ketema
AR	Arba Rakkatte
COD	Chemical Oxygen Demand
EDTA	Ethylene Diamine Tetra-acetic Acid
EC	Electrical Conductivity
ECS	Ethiopian Compulsory Standards
TDS	Total Dissolved Solids
TH	Total Hardness
TSS	Total Suspended Solids
WHO	World Health Organization

Acknowledgments

Many thanks to Oda Bultum University, Research, and Development Office for their financial support.

Author Contributions

Yoobsan Ejeta Amensisa: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing

Berhanu Amenu Abdeta: Funding acquisition, Methodology, Validation, Visualization, Writing – review & editing

Amanuel Ayale Gobosho: Visualization, Writing – review & editing

Mizbawu Kanea Gurmu: Data curation, Formal analysis, Visualization, Software

Data Availability Statement

The raw data sets used and/or analyzed during the present work are available from the corresponding author at reasonable request at any time.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Y. A. Mengstie, W. M. Desta, and E. Alemayehu, "Assessment of Drinking Water Quality in Urban Water Supply Systems: The Case of Hawassa City, Ethiopia," vol. 2023, 2023. https://doi.org/10.1155/2023/8880601

[2] W. Ali, S. Muhammad, and Y. Tepe, "Evaluation of drinking and irrigation water quality, and potential risks indices in the Dera Ismail Khan district, Pakistan," Kuwait Journal of Science, vol. 51, no. 1, p. 100150, 2024. https://doi.org/10.1016/j.kjs.2023.11.001

[3] R. M. Ramanuj, V. Vijaykumar, and S. Varjani, "Quality Evaluation of Ground Water from Borewell for Its Drinking and Agricultural Use," p. 1991, 2018.

[4] W. Bank, "Drinking Water Quality in Ethiopia Drinking Water Quality in Ethiopia," no. December 2017.

[5] E. M. M. Wanda, L. C. Gulula, and G. Phiri, "Determination of characteristics and drinking water quality index in Mzuzu City, Northern Malawi," Physics and Chemistry of the Earth, vol. 50–52, pp. 92–97, 2012. http://dx.doi.org/10.1016/j.pce.2012.09.004

[6] S. N. Pandya, A. K. Rana, and D. K. Bhoi, "Physico-chemical analysis of borewells drinking water of Kapadwanj territory," vol. 5, no. 2, pp. 253–257, 2010. http://dx.doi.org/10.12944/CWE.5.2.05

[7] M. M. Heydari, A. Abbasi, S. M. Rohani, S. Mohammad, and A. Hosseini, "Correlation Study and Regression Analysis of Drinking Water Quality in Kashan City, Iran," vol. 10, no. 3, pp. 315–324, 2013. https://doi.org/10.2004/wjst.v10i3.338

[8] N. Rahmanian et al., "Analysis of Physiochemical Parameters to Evaluate the Drinking Water Quality in the State of Perak, Malaysia," vol. 2015, no. Cd, 2015. https://doi.org/10.1155/2015/716125

[9] P. Kumar, C. Azad, V. Priyadarshini, and S. Harshita, "Hydrogeochemical characterization and water quality evaluation for drinking and irrigation purposes of coastal aquifers of Middle Andaman," Discover Applied Sciences, 2024. https://doi.org/10.1007/s42452-024-05889-z

[10] D. R. Khanna, R. Bhutiani, B. Tyagi, P. K. Tyagi, and M. Ruhela, "Determination of water quality index for the evaluation of surface water quality for drinking purpose," vol. 1, no. 1, 2013.

[11] World Health Organization. Guidelines for Drinking-Water Quality. Geneva: World Health Organization, 2022, pp. 155-200. https://www.who.int/publications/i/item/9789240045064

[12] Ethiopian Standards Agency. Compulsory Ethiopian Standard CES 58, Drinking water specifications. Addis Ababa: Ethiopian Standards Agency; 2013, pp. 4-8. https://www.cmpethiopia.org/media/ethiopian_drinking_water_quality_standard_2013

[13] Z. A. Napacho and S. V Manyele, “Quality assessment of drinking water in Temeke District (part II): Characterization of chemical parameters,” vol. 4, no. November, pp. 775–789, 2010. https://doi.org/10.4314/ajest.v4i11.71349

[14] E. I. Hammad, M. R. Al-Agha, and Y. El-Nahhal, “Enhancing Biogas Production: Influence of Mixing Caw and Chicken Manures,” Energy and Power Engineering, vol. 10, no. 08, pp. 383–397, 2018. https://doi.org/10.4236/epe.2018.108024

[15] C. Radulescu, P. Bretcan, A. Pohoata, D. Tanislav, R. M. Stirbescu, and D. County, “Assessment of drinking water quality using statistical analysis: a case study,” vol. 61, pp. 1604–1616, 2016.

[16] W. H. O. Guidelines, “Nickel in drinking-water,” 2021.

[17] R. Verma, S. Roy, and V. K. Singh, “Water quality assessment and evaluation of human health risk of drinking water in Ranchi District of Jharkhand,” 2024. https://doi.org/10.30574/gscbps.2024.26.2.0057

[18] Reyes-Toscano, C. A., Alfaro-Cuevas-Villanueva, R., Cortés-Martínez, R., Morton-Bermea, O., Hernández-Álvarez, E., Buenrostro-Delgado, O., & Ávila-Olivera, J. A. Hydrogeochemical characteristics and assessment of drinking water quality in the urban area of Zamora, Mexico. Water, 2020, 12(2), pp. 1-26. https://doi.org/10.3390/w12020556.