ATTAHADI MEDICAL JOURNAL
Journal homepage:
http://attahadi.edu.ly/journal/index.php/amj/index

Spectrophotometric Determination of Iron Concentration in Groundwater Samples from Al-Najila Agricultural Area

Khayriya Rahouma[1]*, Ali Ejbali[2], Tariq Muftah[3]

[1]Department of Chemistry, Faculty of Education – Janzour, University of Tripoli, Libya.
[2]Department of Chemical and Environmental Engineering, College of Engineering Technology – Janzour, Libya
[3]Faculty of Science, Sabratha University, Sabratha, Libya.

Keywords.
Iron, Spectrophotometry, Groundwater, Orthophenanthroline.

Received *28 Feb 25*
Accepted *08 April 25*
Published *19 April 25*

ABSTRACT

This study aims to estimate the concentration of iron and assess the extent of groundwater contamination by collecting eighteen random groundwater samples from the Al-Najila agricultural area. Additionally, the study seeks to evaluate the compliance of these concentrations with drinking water quality standards and to identify the environmental and health impacts associated with iron contamination in groundwater. For the purpose, iron concentrations were determined using the FerroVerspectrophotometric method, which involves converting all forms of iron in the sample into a soluble form through a reaction with 1,10-orthophenanthroline present in the reagent, forming an orange-coloured complex. The absorbance was measured using a spectrophotometer (DR 6000) at a wavelength of 510 nm. The results showed that iron concentrations in the samples ranged from 0.03 mg/L to 0.37 mg/L. To verify the accuracy of the analysis, the standard addition method was applied, yielding a linear equation of $y = 2.083x + 0.0348$ with a correlation coefficient of $r^2 = 0.9992$, indicating high precision and consistency of the results. Besides, the obtained values were compared with the Libyan national standards and the World Health Organization (WHO) guidelines for drinking water, both of which set the maximum allowable concentration of iron at 0.3 mg/L. It was confirmed that all samples were within the acceptable range, except for one that slightly exceeded the recommended limit. Conclusively, iron concentrations in the groundwater of the study area generally comply with the established standards. However, continuous monitoring is recommended to track changes in iron levels, identify potential sources of contamination, and implement appropriate preventive measures.

Citation info. Rahouma K, Ejbali A, Muftah T. Spectrophotometric Determination of Iron Concentration in Groundwater Samples from Al-Najila Agricultural Area. Attahadi Med J. 2025;2(2):96-98. https://doi.org/10.69667/amj.25205

INTRODUCTION

Ensuring the safety of drinking water is a critical aspect of public health. Agencies such as the United States Environmental Protection Agency (EPA) and the World Health Organization (WHO) have established comprehensive guidelines to evaluate water quality and its suitability for human consumption [1]. Undeniably, groundwater is a vital resource that supports domestic, agricultural, and industrial needs [2]. However, groundwater contamination by iron remains a significant environmental concern in various regions [3].

Iron, one of the most abundant elements in the Earth's crust, is commonly present in the environment as iron oxides [4]. It can enter groundwater systems through natural weathering processes, particularly when rainwater percolates through iron-bearing rocks, dissolving and mobilizing the element [3]. In addition, anthropogenic sources contribute to iron contamination. These include corroded iron pipes, industrial discharges, and the widespread use of iron in infrastructure, paints, plastics, and water treatment processes [4,5].

Water containing suspended particles rich in iron minerals or elevated concentrations of iron often displays a brownish coloration. Due to oxidation processes, iron can leave reddish or orange stains on kitchen utensils, household appliances, clothing, and various surfaces. Although iron in drinking water is generally considered safe when present within recommended regulatory limits, iron deposits may contain trace contaminants or serve as a medium for bacterial growth, potentially posing risks to human health [6].

Iron is an essential micronutrient for humans, playing a crucial role in numerous physiological functions [7]. It is a key component of haemoglobin, the protein responsible for oxygen transport in red blood cells. Iron also contributes significantly to metabolic processes by activating enzymes, enhancing immune function, and supporting energy production. However, iron deficiency is a leading cause of anaemia, a condition that affects populations worldwide, and is also associated with compromised immunity, insomnia, and other health issues. Conversely, excessive concentrations of iron and its compounds may result in adverse health effects, including lethargy, depression, coma, cardiovascular diseases, arthritis, hair loss, and additional complications [8,9]. Correspondingly, iron is essential for the synthesis of chlorophyll in plants, and both iron deficiency and toxicity can adversely affect crop yield and quality [10,11]. Previous research has documented elevated iron levels in groundwater in several parts of the world, often surpassing WHO's recommended limits [12–15]. Thus, regular monitoring and assessment of groundwater quality are crucial for public safety. This study investigates iron concentrations in groundwater from the Al-Najila agricultural area using a spectrophotometric method. The findings aim to provide insights into the quality of groundwater in the region, identify potential sources of contamination, and determine the water's suitability for drinking and agricultural purposes.

*Corresponding E-mail addresses: kh.rahuma@uot.edu.ly

MATERIALS AND METHODS

Sample Collection

As stated earlier, eighteen groundwater samples (*n = 18*) were collected from the Al-Najila agricultural area in May 2023. Samples were obtained using 0.5-liter pre-cleaned plastic bottles. Before sampling, well pumps were operated for at least 10 minutes, and bottles were rinsed with well water before collection. All samples were transported to the laboratory and analyzed for iron concentration within 24 hours.

Reagents and Standards

Iron analysis was conducted using the FerroVer Iron Reagent (Iron PHEN-ANTHROLINE). Reagents included 1,10-phenanthroline-p-toluenesulfonic acid salt, sodium citrate, sodium hydrosulfite, sodium metabisulfite, and sodium thiosulfate. Iron standard solutions (1000 mg/L) were used to prepare working solutions of 100 ppm, 25 ppm, and 10 ppm.

Equipments and apparatus

The equipments used in this study included a UV-Visible Spectrophotometer (HACH – DR6000), an analytical balance, a watch glass, a spatula, 100 ml, 250 ml beakers, a glass stirring rod, a funnel, a micropipette, a 50 ml pipette,1000 ml volumetric flask.

Preparation of the Iron standard curve

A blank was prepared using 10 mL of distilled water and one sachet of FerroVer reagent. For calibration, five iron standard solutions were prepared by pipetting (0.05, 0.10, 0.30, 0.50, 0.70 mL) of a 10-ppm solution into cuvettes, then diluting to 10 mL. The reagent was added, and samples were left to react for 3 minutes before absorbance was measured at 510 nm. The resulting calibration curve exhibited a strong linear relationship between absorbance and concentration ($r^2 = 0.9961$).

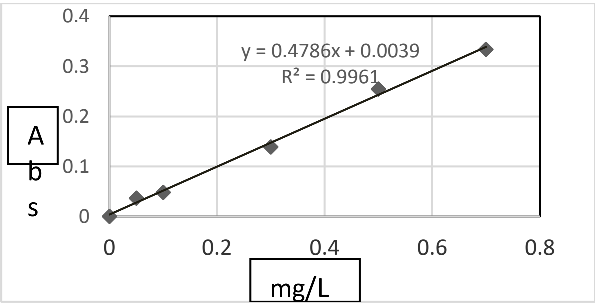

Figure 1. Iron PHEN-ANTHROLINE Complex titration curve at wavelength 510 nm

Principle of Operation

This analytical method involves converting all iron species—both soluble and insoluble—into a soluble ferrous (Fe^{2+}) form using a specific reagent. The ferrous ions then react with 1,10-phenanthroline, forming a stable orange-colored complex. The intensity of this color is directly proportional to the concentration of iron in the sample. The absorbance of the resulting complex is measured spectrophotometrically at a wavelength of 510 nm, allowing for quantitative determination of iron concentration.

Chemical reaction equation of iron with 1,10-orthophenanthroline**:**

$$Fe^{2+} + 3phenH^{+} \leftrightarrow Fe(phen)_3^{2+} + 3H^{+}$$

Analytical Procedures

The spectrophotometer was set to the FerroVer Iron 265 program, with the measurement wavelength adjusted to 510 nm. A Planck's solution was used to zero the instrument, with a baseline reading of 0.00 mg/L Fe displayed on the screen.

A 10 mL aliquot of the groundwater sample was transferred into a clean sample cell. One sachet of FerroVer Iron Reagent was then added to the sample, which was thoroughly shaken and allowed to react for 3 minutes. During this time, an orange color developed, indicating the presence of iron. The exterior of the sample cell was dried to remove any moisture or fingerprints and subsequently placed into the designated chamber of the spectrophotometer. Upon pressing the "Read" button, the iron concentration is measured on the device, and the results appear on the screen in mg/l [16].

Standard Addition Method

Due to accuracy verification of the measurement, the standard addition method was employed. Initially, the iron concentration in a 10 mL sample was measured, yielding a value of 0.042 mg/L. Subsequently, 0.1 mL of a 25-ppm iron standard solution was added incrementally to the same sample three times, corresponding to added volumes of 0.1 mL, 0.2 mL, and 0.3 mL, respectively.

After each addition, the sample was shaken, allowed to react for 3 minutes, and the absorbance was measured at 510 nm. Following the standard additions, the measured iron concentration is equal to 0.043 mg/L.

A standard curve was constructed by plotting the total iron concentration (mg/L) against the volume of standard solution added. The resulting linear regression equation demonstrated excellent linearity, with a correlation coefficient $r^2 = 0.9992$, indicating a high degree of accuracy and reproducibility in the method [16].

Table 1. Standard addition and percentage recovery (%)

Standard iron solution (ml)	Fe (mg/l)	Recovery %
0.00 ml	0.042 mg/L	100%
0.1 ml	0.234 mg/L	84.1%
0.2 ml	0.448 mg/L	84.3%
0.3 ml	0.665 mg/L	86.4%

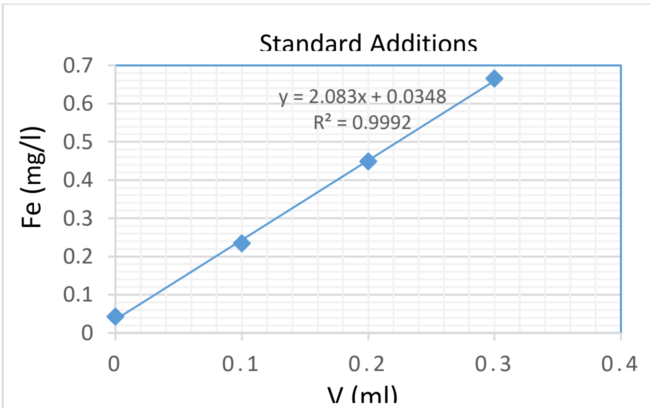

Figure 2. The standard curve represents the relationship between the volume of the added standard iron solution and the concentration of iron in the sample with the standard addition at a wavelength of 510 nm.

RESULTS AND DISCUSSION

In this study, the concentration of iron in groundwater samples from the Al-Najila agricultural area was determined using spectrophotometric analysis. The method involved the formation of a colored complex

between iron and the FerroVer (1,10-phenanthroline) reagent, with absorbance measurements taken at 510 nm using a UV-Vis spectrophotometer (HACH DR6000). The measured concentrations were compared to both the Libyan standard and the World Health Organization (WHO) guidelines for drinking water quality.
The final results of iron concentration (mg/L) in the collected groundwater samples are shown in Table 2 below:

Table 2. Iron concentration (mg/L) in the selected samples

Sample Number	Concentration (mg/L)	Sample Number	Concentration (mg/L)
1	0.19	10	0.09
2	0.05	11	0.11
3	0.03	12	0.05
4	0.37	13	0.03
5	0.21	14	0.03
6	0.04	15	0.06
7	0.06	16	0.07
8	0.05	17	0.13
9	0.04	18	0.14

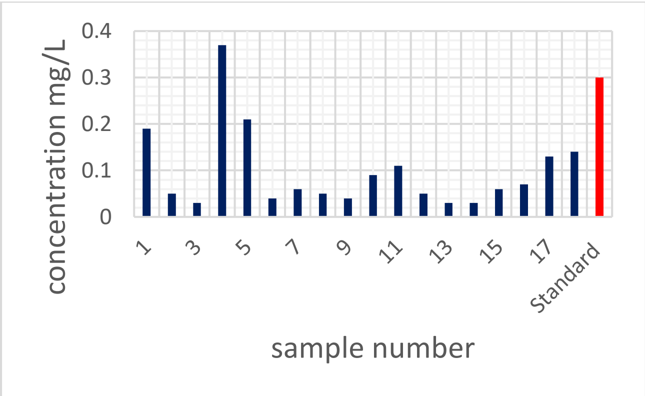

Figure 3. The results of comparing the samples with the Libyan standard

As illustrated in Figure 3), the results were compared against the Libyan national standard and the WHO guideline for iron concentration in drinking water, both of which set a maximum permissible limit of 0.3 mg/L [17]. The iron concentrations in the groundwater samples ranged from 0.03 mg/L to 0.37 mg/L.
Most samples were within the acceptable range, except for Sample 4, which recorded a concentration of 0.37 mg/L, slightly exceeding the permissible limit. This deviation may be attributed to a set of environmental and anthropogenic factors, including: Corrosion of iron pipes used in water infrastructure. The geochemical composition of the surrounding soil and rock formations. Agricultural activities involving fertilizers and chemical inputs. Contamination from sewage or industrial effluents. In a more accurate sense, these factors may contribute to the leaching and mobilization of iron into groundwater systems, impacting overall water quality.

CONCLUSION

Given the critical role of water in sustaining life, and the reliance of many communities on groundwater sources for drinking and domestic use, this study aimed to evaluate the concentration of iron in groundwater samples from the Al-Najila agricultural region. The goal was to assess compliance with national and international water quality standards. Overall, the results indicated that the iron concentrations were within the acceptable limits set by both the Libyan national standard and the World Health Organization guidelines, except a single sample slightly exceeding the recommended threshold. While the majority of groundwater in the study area is suitable for human consumption in terms of iron content, the presence of elevated levels in some areas highlights the need for regular monitoring and potential mitigation measures to ensure long-term water quality and safety.

Conflict of interest. Nil

References

1. U.S. Environmental Protection Agency. Secondary Drinking Water Standards: Guidance for Nuisance Chemicals [Internet]. United States Environmental Protection Agency; [cited 2017 Oct 7]. Available from: https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals
2. Carrard N, Foster T, Willetts J. Groundwater as a Source of Drinking Water in Southeast Asia and the Pacific: A Multi-Country Review of Current Reliance and Resource Concerns. University of Technology Sydney; 2019.
3. Rapant S, Krcmová K. Health risk assessment maps for arsenic groundwater content. Environ Geochem Health. 2007;29:131-41.
4. World Health Organization. Guidelines for Drinking-Water Quality. 3rd ed. Vol. 1. Geneva: WHO; 2008.
5. Joint FAO/WHO Expert Committee on Food Additives. Toxicological Evaluation of Certain Food Additives and Food Contaminants. Cambridge University Press; 1983.
6. Ibrahim AQ, Onyenekwe PC, Nwaedozic IM. An efficiency assessment of Lower Usuma Water Treatment Plant in Abuja Metropolis, Nigeria. Environ Sci Toxicol Food Technol. 2014;8(2):46-53.
7. Liberal Â, et al. Fighting iron-deficiency anemia: innovations in food fortificants and biofortification strategies. Foods. 2020;9(12).
8. Cronin SJF, et al. The role of iron regulation in immuno-metabolism and immune-related disease. Front Mol Biosci. 2019;6.
9. Clara C. Iron deficiency: new insights into diagnosis and treatment. Hematology Am Soc Hematol Educ Program. 2015;2015(1):8-13.
10. Rout GR, Sahoo S. Role of iron in plant growth and metabolism. Rev Agric Sci. 2015;3:1-24.
11. Rodrigues Filho J, et al. Effects of Fe toxicity on germination and initial growth of Carica papaya L. Sci Plena. 2020;16.
12. Karakochuk CD, et al. Elevated levels of iron in groundwater of Prey Veng Province in Cambodia: a possible factor contributing to high iron stores in women. J Water Health. 2015;13(2):575-86.
13. Oyem HH, Oyem IM, Usese AI. Iron, manganese, chromium, cadmium, zinc and arsenic groundwater contents in Nigeria. SpringerPlus. 2015;4.
14. Melegy AA, et al. Geochemical mobilization of some heavy metals in water resources in Sohag, Egypt. Arab J Geosci. 2014;7:4541-52.
15. Agoub AOM, Jahan FAY. A study of groundwater contamination with heavy elements in Al-Dafiniyah, Misurata, Libya. Glob Libyan J. 2022.
16. HACH Company. Iron, Total, FerroVer Method 8008. 9th ed. 2014.
17. Libyan National Center for Standardization and Metrology. Drinking Water Standards. LNCSM 82. 2nd ed. 2015.