

Research Article

Evaluation of Two Spectrometric Approaches for Measuring Metal Concentrations in Drinking Water

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Abstract

This study aimed to compare the performance of photometric analysis and flame atomic absorption spectrophotometry (FAAS) in determining iron concentrations in water samples. Thirty samples were collected from wells located in the Anani and Gonzacque-ville neighborhoods and analyzed using both techniques. Photometric results indicated that 26 out of 30 samples had iron concentrations below the Ivorian regulatory limit of 0.3mg/L, while three samples exceeded this threshold. In contrast, AAS measurements showed that all samples complied with the standard, with no exceedances recorded. Statistical analysis revealed a significant difference between the two methods, with photometric readings generally yielding higher iron concentrations than those obtained via AAS. This discrepancy highlights the importance of employing more precise analytical techniques such as FAAS for routine water quality monitoring, particularly when assessing critical parameters like iron.

Keywords

Photometer, Flame Atomic Absorption Spectrophotometer, Iron, Water

1. Introduction

Water is essential to life [1]. To maintain good health, it is crucial to have access to safe drinking water in sufficient quantities for daily needs [2]. Drinking water is defined as water that can be consumed without posing a risk to human health. Therefore, water that does not meet potability standards may present health risks and contribute to the emergence of waterborne diseases [3]. Consequently, monitoring water quality is vital to detect the presence of pathogenic agents and ensure the safety of consumed water [3]. Spectrometric techniques are commonly used for quality control purposes [4]. In Côte d'Ivoire, the agency responsible for monitoring drinking

water quality routinely uses portable photometers at sampling sites. To assess the reliability of this method, a comparative study was conducted with FAAS. The objective of this study was to verify iron concentration measurements in drinking water samples.

2. Materials and Methods

2.1. Equipment and Reagents

The equipment used in this study included a pH meter

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(HACH HQ 11d[®], France), a turbidimeter (TURB 430 IR[®], France), a photometer (Palintest 7100[®], United Kingdom), and a flame atomic absorption spectrophotometer (FAAS Agilent[®], United States). Standard laboratory glassware was employed throughout the analyses. Analytical-grade reagents were used, including iron reagent tablets (Iron HR), nitric acid, and distilled water.

2.2. Iron Determination

a. Using the Palintest[®] Photometer

For photometric analysis, a 10mL volume of water was collected using a macropipette and transferred into a clean test tube. A crushed and homogenized iron reagent tablet ("Iron HR") was then added to the sample. After a one-minute waiting period to allow optimal color development, the photometric measurement was performed using program Phot 19, corresponding to the iron determination protocol. Absorbance was measured at 520nm, and the iron concentration (mg/L) was directly displayed by the device [5].

b. Using Flame Atomic Absorption Spectrophotometry (FAAS)

A 100mL volume of water sample was collected, filtered, and acidified by adding 1mL of concentrated nitric acid. A three-point calibration curve was prepared from a 1mg/L stock iron solution, diluted with nitric acid-acidified water to obtain standard solutions of 1, 3, and 6mg/L. Iron analysis in the water samples was performed under the following conditions:

Wavelength: 248.3nm - Flame type: Air-acetylene - Air flow rate: 10L/min - Acetylene flow rate: 2 L/min - Reading mode: Direct absorbance - Reading time: Average of three consecutive readings - Injection volume: 5mL per sample - Analytical blank: Distilled water acidified with 5% nitric acid - Calibration curve: Standards at 1, 3, and 6mg/L.

2.3. Statistical Tests

A statistical analysis was conducted to compare two quantitative variables corresponding to the mean iron concentrations obtained. The comparison test was performed using R software (Version 2022.07.2-576) and Microsoft Excel (Version 2021). Statistical analyses including the Shapiro-Wilk test, F-test, and the non-parametric Wilcoxon test were conducted.

3. Results

According to the results obtained (Table 1), photometer readings indicated that the majority of samples (26 out of 30) had iron concentrations below the regulatory threshold (Figure 1). One sample (Sample 24) showed an iron concentration equal to the standard (0,3mg/L), while three samples (Samples 28, 29, and 30) exceeded the permissible limit (Figure 2). In contrast, results obtained using Flame Atomic Absorption Spectroscopy (FAAS) revealed that all analyzed samples had iron concentrations below the regulatory threshold (Figure 1).

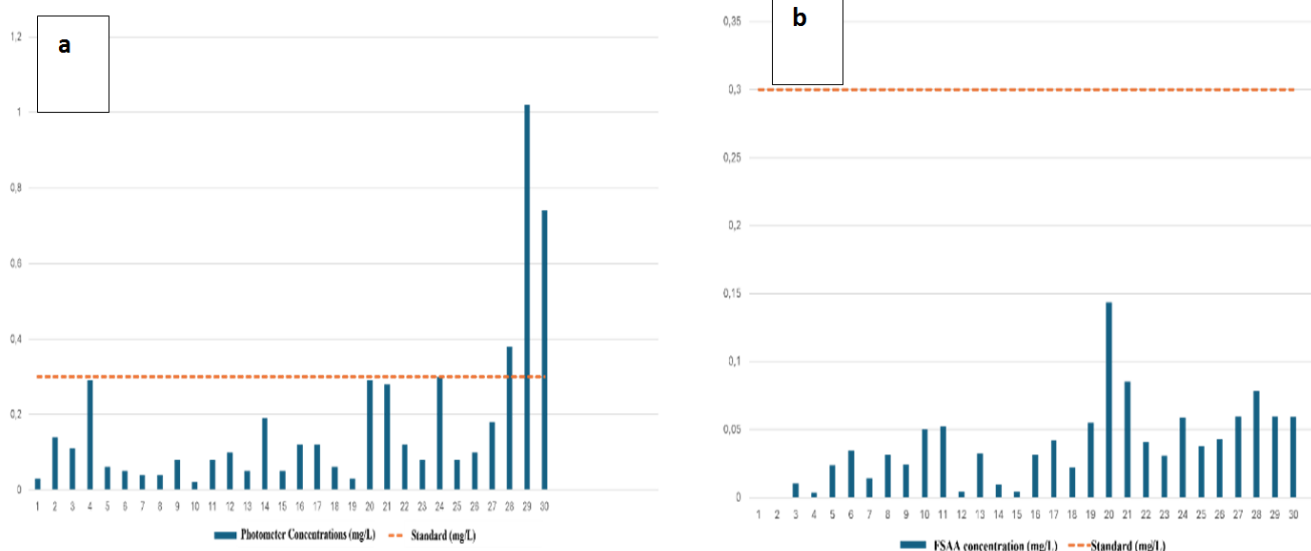


Figure 1. The histogram of iron concentrations measured by photometer (a) and FAAS (b).

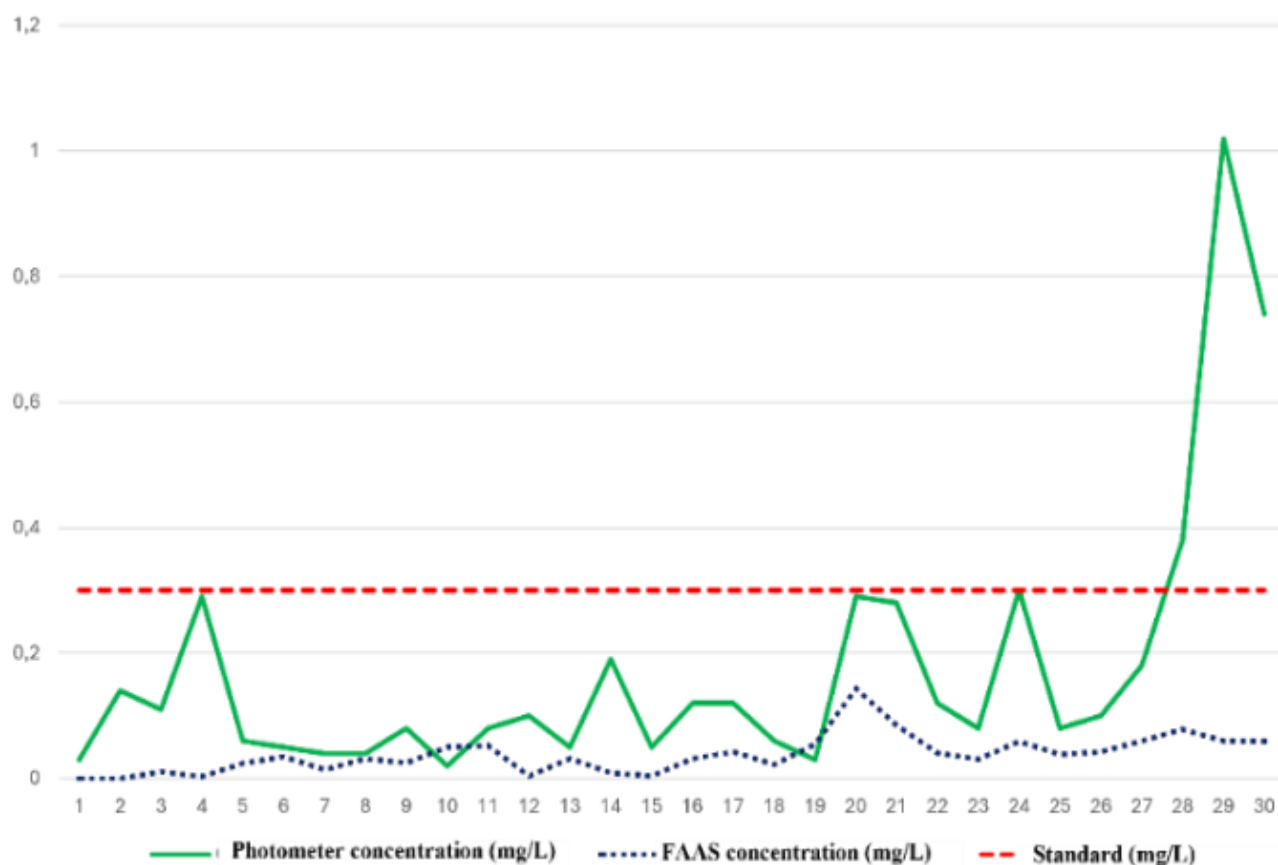


Figure 2. Trend curve of iron concentrations obtained by photometry and FAAS.

The Shapiro-Wilk test indicated that the data were not normally distributed (p -value < 0.05). The F-test revealed significantly different variances between the two groups (p -value < 0.05), justifying the use of a non-parametric approach. The Wilcoxon test showed a statistically significant difference between M1 and M2 (p -value < 0.05), with values obtained using the photometer being significantly higher than those obtained via FAAS. These results confirm that the data are non-normally distributed, the group variances are unequal, and there is a significant difference between the two analytical methods.

Table 1. Iron contents by photometer and FAAS per sample.

Sample number	Photometer assay (mg/l)	FAAS assay (mg/l)
E1	0.03	< at the detection limit
E2	0.14	< at the detection limit
E3	0.11	0.0105
E4	0.29	0.0034
E5	0.06	0.0237
E6	0.05	0.0345

Sample number	Photometer assay (mg/l)	FAAS assay (mg/l)
E7	0.04	0.0141
E8	0.04	0.0312
E9	0.08	0.0245
E10	0.02	0.0502
E11	0.08	0.0520
E12	0.10	0.0044
E13	0.05	0.0319
E14	0.19	0.0094
E15	0.05	0.0043
E16	0.12	0.0318
E17	0.12	0.0424
E18	0.06	0.0223
E19	0.03	0.0550
E20	0.29	0.1435
E21	0.28	0.0851
E22	0.12	0.0409

Sample number	Photometer assay (mg/l)	FAAS assay (mg/l)
E23	0.08	0,0308
E24	0.30	0,0588
E25	0.08	0,0378
E26	0.10	0,0425
E27	0.18	0,0596
E28	0.38	0,0781
E29	1.02	0,0596
E30	0.74	0,0592
Average	0.174	0.038
Standard deviation	0.217	0.030
Mean standard error	0.039	0.005

4. Discussion

The comparative analysis of iron concentrations in groundwater using photometry and FAAS reveals notable discrepancies between the two methods. While photometric analysis identified three samples exceeding the recommended iron threshold, FAAS results indicated that all samples remained within acceptable limits. This divergence underscores the importance of methodological choice in environmental monitoring, particularly when assessing trace metal concentrations. Photometry, although operationally simple and suitable for field use, is susceptible to matrix interferences and lacks the specificity required for accurate quantification in complex samples. The elevated values observed may stem from colorimetric interferences.

Or insufficient sample preparation, as the method does not typically involve acid digestion a step that enhances analytical reliability by minimizing the influence of organic and inorganic contaminants [6, 7].

In contrast, FAAS offers superior sensitivity and selectivity by directly measuring the absorption of light by vaporized atoms. Its robustness against interferences, especially when corrective techniques are applied, makes it a more reliable tool for trace metal analysis [4]. The statistical comparison of results confirms that photometric readings tend to overestimate iron concentrations, potentially leading to false-positive assessments of water quality risks.

From a public health perspective, accurate determination of iron levels is essential. Excess iron not only affects organoleptic properties of water such as taste and color but also poses health risks, particularly in vulnerable populations like children [3, 9].

The findings also highlight the limitations of portable photometers like the Palintest[®] device, which, despite their accessibility and ease of use, may not be suitable for rigorous

environmental assessments. For research and regulatory purposes, especially in contexts where water quality directly impacts public health, FAAS remains the reference method [8, 9].

Future studies should explore hybrid approaches, combining the accessibility of field photometry with confirmatory laboratory techniques such as FAAS. Additionally, capacity-building efforts in regions relying on simplified methods should prioritize training in sample preparation and interpretation of results to ensure data reliability and informed decision-making.

5. Conclusion

This study was initiated to evaluate and compare the analytical performance of photometry and FAAS in the determination of iron concentrations in drinking water. The results indicate that iron levels measured by photometry are, in most cases, below regulatory thresholds but consistently higher than those obtained via FAAS. This discrepancy was statistically validated. FAAS stands out for its enhanced sensitivity, superior precision, and reduced susceptibility to analytical interferences, although its implementation is more time-consuming. These findings strongly support the integration of FAAS into the equipment of laboratories responsible for water quality monitoring, in order to ensure the reliability and rigor of analytical results.

Abbreviations

FAAS Flame Atomic Absorption Spectrophotometry

Author Contributions

Kpaib é Sawa André Conceptualization, Methodology, Writing – original draft, Supervision

Yao Marcelle: Formal Analysis

Abl é Nina: Methodology

Yao Jean Simon: Methodology

Amin N'cho Christophe: Methodology, Supervision

Conflicts of Interest

The authors declare no conflicts of interest.

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