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Proposed Smartphone-Based Colorimetric Determination of Nitrite in Drinking Water

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Abstract. Nitrite is an important indicator in drinking-water surveillance because it is reactive, may change during storage, and can be associated with treatment or distribution-system failures. This methodological study proposes a student-accessible procedure that combines the Griess reaction with smartphone digital image colorimetry. Sulfanilamide and N-(1-naphthyl)ethylenediamine form a magenta azo dye; a controlled light box, fixed region of interest and green-channel image absorbance provide the analytical response. Calibration, blank correction, duplicate preparation, spike recovery and comparison with UV-visible spectrophotometry are proposed as validation steps. Twelve peer-reviewed studies from 2023-2026 were evaluated to define controls for illumination, device variation and reagent handling. Because no field measurements are reported, stated performance limits are validation targets to be tested experimentally. The proposed method is intended for education and preliminary screening, whereas regulatory decisions require confirmatory analysis.

Keywords: *nitrite; drinking water; smartphone colorimetry; Griess reaction; digital image analysis; method validation*

1. Introduction

Nitrite (NO_2^-) is an intermediate of the nitrogen cycle and may reach water through fertilizer runoff, wastewater intrusion, nitrification or incomplete treatment. It is more reactive than nitrate and can change between sampling and analysis. Its toxicological importance is linked mainly to methaemoglobin formation and conditions that favour N-nitroso compounds. Results must clearly state whether concentration is expressed as NO_2^- or as nitrite-nitrogen because conversion between the two introduces a factor of 3.284. A screening procedure must therefore combine rapid measurement with

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controlled sampling, timing and unit reporting [7].

A smartphone records a processed image rather than concentration itself. Pixel values depend on illumination, camera response, white balance, exposure and compression. The analytical design must control these variables as deliberately as spectrophotometry controls wavelength, path length and baseline. Recent studies therefore use light boxes, internal colour references, marker-guided strips and reference calibration [4-6,8,9,11,12].

This study proposes a reproducible Griess-smartphone protocol, specifies validation criteria and defines the method's proper role as a low-cost screening and teaching tool.

2. Analytical principle

2.1. Chemistry of the Griess reaction

In acidic solution, nitrite forms nitrous acid and reactive nitrosating species. Sulfanilamide is diazotized, and the product couples with N-(1-naphthyl)ethylenediamine (NED) to form a magenta azo dye. When acidity, reagent order, temperature and reaction time are fixed, colour intensity is proportional to nitrite concentration. Recent work has retained this mechanism while modifying chromogenic agents, paper supports or signal processing [1-3,8-10].

$$NO_2^- + H^+ \rightleftharpoons HNO_2 \rightarrow diazotization \rightarrow azo\ dye$$

2.2. Digital image response

The magenta product absorbs strongly in the green region; consequently, the mean green value of a fixed image region normally decreases as nitrite increases. A logarithmic response, $A^G = \log_{10}(G_0/G)$, more closely resembles absorbance than a raw channel value, where G_0 and G are blank and sample green values recorded under identical conditions.

$$A^G = log_{10}(G_0/G)$$

The calibration relation $A^G = mC + b$ is used to calculate $C = (A^G - b)/m$. RGB ratios or CIELAB coordinates may serve as robustness checks. Internal neutral patches captured in the same image help reveal illumination drift and device-dependent colour shifts [6,11].

3. Materials and methodology

3.1. Study design and scope

The work integrates a critical synthesis of twelve peer-

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reviewed sources published between 2023 and 2026 with a laboratory-ready protocol. No field measurements or empirical performance are claimed.

3.2. Reagents, equipment and safety

Required materials are analytical-grade sodium nitrite, sulfanilamide, NED dihydrochloride, phosphoric acid, deionized water, volumetric equipment, identical clear vials, a smartphone and a matte imaging box. A practical reagent pair is 1.0% (m/v) sulfanilamide in 5% (v/v) phosphoric acid and 0.10% (m/v) NED. Reagents should be protected from light and stability-tested. Gloves, eye protection and controlled chemical-waste collection are mandatory.

3.3. Standards and samples

A 1000 mg L^{-1} stock expressed as NO_2^- is prepared from 1.500 g dry $NaNO_2$ per litre. A fresh intermediate solution is diluted to at least six standards, for example 0.00, 0.05, 0.10, 0.25, 0.50, 0.75 and 1.00 mg L^{-1}. Clean amber containers are used for samples, which should be analysed promptly. Filtration is permitted for suspended matter only when the measurand is reported as dissolved nitrite. Coloured, chlorinated or turbid matrices require recovery testing or standard addition.

$$C(NO_2^-) = 3.284 \times C(NO_2^- - N)$$

3.4. Colour development and image acquisition

Transfer 5.00 mL of each standard, blank and sample to identical vials. Add 0.50 mL sulfanilamide reagent, mix and wait 2 min; add 0.50 mL NED, mix and develop colour for 10 min at room temperature. Use the same timing for all solutions. Include a reagent blank, a mid-range control and independently prepared duplicates in every batch.

Image each vial in a closed matte enclosure with a stable white LED, fixed distance, angle and position. Disable flash, filters and HDR; lock focus, exposure, ISO and white balance when possible. Include white, grey and black reference patches. Select the central solution area and exclude glare, meniscus, labels and vessel edges.

3.5. Image processing, calibration and validation

Calculate mean R, G and B values from an identical region of interest and apply a documented rule for excluding glare. Fit ordinary least-squares calibration after inspecting

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residuals. Curvature or channel saturation requires dilution or a narrower range; a high R^2 alone is insufficient evidence of linearity.

Validation covers blank stability, linearity, repeatability, between-day precision, recovery, dilution integrity, interference and comparison with UV-visible Griess spectrophotometry at approximately 540 nm. Practical student targets are $R^2 \geq 0.995$ without systematic residuals, RSD ≤ 10%, recovery of 80–120%, bias within ±10%, and a detection limit preferably no higher than 0.05 mg L^{-1}. These are study criteria, not universal legal limits.

$$Recovery\ (\%) = [(C_{spiked} - C_{unspiked})/C_{added}] \times 100$$
$$RSD\ (\%) = (s/\bar{C}) \times 100$$

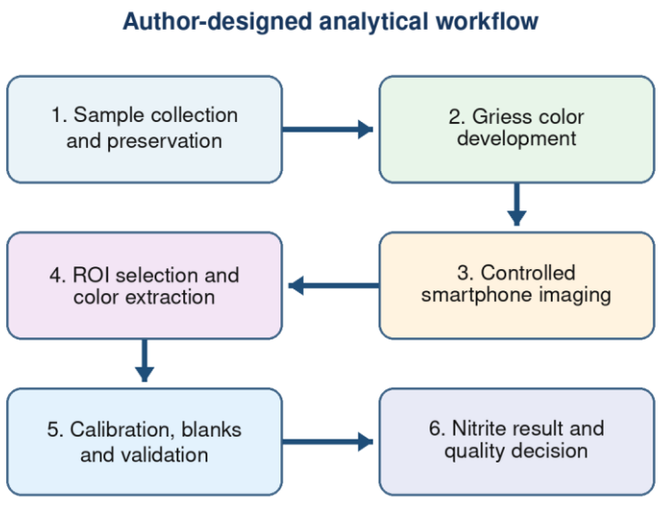

Figure 1
Author-designed scheme for smartphone-based nitrite determination.

4. Literature-based evaluation

4.1. Lessons from recent analytical studies

Recent literature shows that smartphone sensing integrates chemistry, support material, image acquisition and calibration. Natural reagents can reduce hazardous inputs but require composition control [1]. Nanoparticle and quantum-dot systems provide sensitive, multiple signals, although their preparation is less suitable for an introductory laboratory [2-4]. Direct water colorimetry,

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marker-guided strips and origami Griess devices demonstrate the value of fixed imaging, internal references and reduced reagent handling [5,6,8,9].

Table 1

Comparison of recent smartphone-compatible nitrite approaches

Study	Analytical design	Lesson for the proposed method
Yardımcı, 2023 [1]	Green-tea chromogenic system with smartphone readout	Greener chemistry is possible, but reagent composition must be standardized.
Wang et al., 2023 [4]	Smartphone-integrated paper sensor with dual optical signals	Multiple signals improve confidence but require advanced sensing materials.
Khoshmaram and Tabaghchi, 2024 [5]	Digital image colorimetry for aqueous nitrite	Fixed imaging conditions and a defined colour response are essential.
Gusev et al., 2024 [6]	Reference-marked strips for inexperienced users	Internal references and fiducial markers reduce positioning and lighting errors.
Gregucci et al., 2025 [9]	Origami paper sensor with immobilized Griess reagents	Low reagent handling improves portability; humidity and shelf life need testing.
Quoc et al., 2026 [11]	Reference calibration and ensemble machine learning	Cross-device accuracy improves when colour references and diverse training data are used.

4.2. Expected calibration behaviour and channel selection

Increasing nitrite should increase magenta intensity and produce a positive A^G slope. A coloured or non-uniform blank indicates contamination, degraded reagent or incorrect imaging. Saturation at the upper standard must be corrected by dilution rather than by choosing a complex model merely for a larger R^2. The green channel should be selected before unknowns are analysed. Machine-learning models can improve cross-device prediction when trained on large, diverse and reference-calibrated image sets [11], but a small student dataset is better served by transparent univariate calibration.

4.3. Sources of uncertainty and interference

Major physical uncertainties are LED spectrum, camera processing, distance, angle, vessel geometry and reflection. Chemical uncertainties include standard preparation, nitrite

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stability, acidity, reagent volumes, temperature and reaction time. Residual chlorine, dissolved colour, iron, turbidity or reducing compounds may bias the reaction or image. Reference patches reveal illumination drift but also require controlled printing and storage. Persistent matrix effects require standard addition or confirmatory spectrophotometry [6,11].

4.4. Sustainability and educational value

Educationally, the experiment links diazotization chemistry with calibration, residual analysis, recovery and uncertainty. Students prepare standards, distinguish NO_2^- from NO_2^--N, control imaging conditions and verify calculations independently. The smartphone functions as an analytical detector whose limitations must be evaluated, not as a decorative substitute for an instrument. Miniaturized volumes can reduce waste when pipetting accuracy and sensitivity remain adequate [1,8–10].

4.5. Limitations and implementation pathway

Because this methodological article contains no verified field concentrations, it cannot demonstrate that a water source meets a legal requirement. Implementation should retain raw images and calculation files, report the phone model and camera settings, test several water matrices, and compare representative samples with spectrophotometry. Only data that satisfy the predefined criteria should be added as experimental results; values near a regulatory threshold require confirmation by an accredited laboratory.

5. Conclusion

Smartphone-based colorimetry can support low-cost nitrite screening when the Griess reaction, illumination, image acquisition and calibration are treated as one analytical system. The proposed workflow uses fixed reaction timing, a controlled enclosure, internal references, predefined green-channel response and explicit validation. Recent studies confirm the value of reference calibration and portable supports while also demonstrating persistent device and matrix effects. The proposed workflow is therefore potentially suitable for undergraduate analytical chemistry and preliminary screening, but regulatory conclusions require experimentally verified performance and confirmatory laboratory analysis.

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