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Rapid Determination of Copper(II) Ions in Drinking Water Using Plant-Derived Fluorescent Carbon Dots

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Abstract. This methodological article proposes a rapid fluorescence-quenching assay for Cu(II) in drinking water using plant-derived carbon dots. Studies from 2023–2026 guide precursor selection, synthesis, signal processing and validation. The workflow integrates hydrothermal preparation, purification, controlled fluorescence measurement, matrix-matched calibration and reference-method confirmation. No original measurements are claimed; analytical performance remains a validation requirement. The design is intended for green analytical-chemistry research and preliminary screening.
Keywords: *Cu(II); carbon dots; fluorescence; drinking water; green analysis*

1. Introduction

Copper is an essential trace element, but excessive dissolved copper can impair water quality and create health and aesthetic concerns. Conventional determination by atomic absorption or inductively coupled plasma spectrometry is reliable, yet it requires laboratory infrastructure. Fluorescent carbon dots offer a complementary screening route because they are water-dispersible, photoluminescent and rich in surface groups that can coordinate metal ions. Plant residues add a circular-chemistry advantage by converting low-value biomass into a sensing material. Recent reviews emphasize both the promise and the strong dependence of plant-derived dots on precursor composition and synthesis history [4,10,12]. This work develops a publication-ready analytical framework for Cu(II) screening without presenting unperformed experiments.

2. Recent evidence and research need

Current evidence supports several renewable precursors. Mandarin-peel dots have been evaluated in tap and drinking water [5]; lemon-peel N,Si-codoped dots showed Cu(II)-

dependent fluorescence quenching [6]; amine-functionalized lignin dots enabled selective trace sensing in aqueous media [7]; and pine-cone lignin with lysine produced nitrogen-doped dots for water analysis [1]. Green-precursor dots were also tested in river samples [2]. Dual-emission, magnetic and paper-supported systems illustrate how internal referencing, separation and portable formats can improve robustness [3,8,9]. The remaining need is not another isolated fluorescence response, but a complete method connecting precursor control, purification, quenching mechanism, matrix effects, calibration and confirmatory analysis.

3. Formation and optical properties of plant-derived carbon dots

Hydrothermal treatment dehydrates, condenses and carbonizes sugars, phenolics, amino acids and lignocellulosic fragments. The nanoscale carbon cores carry oxygen- and nitrogen-containing surface states that support water solubility and fluorescence. Because a botanical precursor is heterogeneous, its species, storage and pretreatment become analytical variables. Temperature and time influence particle size and conjugation, whereas pH and dopants alter surface passivation. Dialysis or ultrafiltration is essential because fluorescent molecular by-products can mimic carbon-dot emission. UV–visible spectra, excitation–emission maps, quantum yield, FTIR, XPS, TEM and storage studies should be interpreted together [4,10,12]. Bright emission alone does not prove reproducibility.

4. Cu(II)-induced fluorescence response

Cu(II) can coordinate carboxylate, hydroxyl and amino groups on the carbon-dot surface and reduce fluorescence through electron or energy transfer, static complex formation, dynamic collisions or an inner-filter contribution. Static quenching changes ground-state association, while dynamic quenching shortens fluorescence lifetime; inner-filter effects arise when Cu-containing species absorb excitation or emission light. Recent studies report more than one mechanism, so the selected dots must be tested rather than assigned a pathway by analogy [2,6,8,10]. Absorption spectra, lifetime measurements, temperature dependence and Stern–Volmer behavior should be combined.

$$F_0 / F = 1 + KSV[Cu^{2+}]$$

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Here F0 and F are blank and Cu(II)-exposed fluorescence intensities. Curvature requires a restricted range or a justified nonlinear model.

5. Choice of precursor and sensor architecture

Citrus peel is proposed as the primary precursor because it is abundant, easily washed and supported by direct drinking-water evidence [5,6]. A nitrogen donor such as lysine may be evaluated as a controlled passivating reagent, following the lignin-based strategy reported in 2026 [1]. The study should compare undoped and nitrogen-modified dots using equal precursor carbon mass, reaction volume and purification conditions. Selection is based on batch yield, quantum yield, blank stability, Cu(II) response, ion selectivity and recovery in representative waters—not brightness alone. A single-emission fluorimeter is the simplest laboratory readout; a dual-emission or reference-dye format may later reduce source-intensity and imaging variation [3,8]. All additives must be disclosed when the method is described as plant-derived.

6. Recent systems and design implications

Recent publications demonstrate that precursor identity, surface modification and readout format are inseparable from analytical performance. Their numerical limits should not be compared without considering matrix, calibration model and instrumentation. Table 1 therefore summarizes transferable design lessons rather than ranking unlike assays.

Table 1

Selected recent Cu(II) carbon-dot systems and lessons for method design

Recent system	Source	Matrix / format	Design implication
Pine-cone lignin N-CQDs	[1]	Water; fluorescence	Renewable lignin plus N-doping
Green-precursor CDs	[2]	River water; fluorescence	Static quenching must be verified
Mandarin-peel CDs	[5]	Tap/drinking water	Direct evidence for fruit-peel CDs
Lemon-peel N,Si-CDs	[6]	Aqueous Cu(II)	Surface chemistry controls response
Amine-lignin CQDs	[7]	Aqueous trace Cu(II)	Functionalization can improve affinity

7. Author-designed analytical scheme

The scheme links material preparation to the analytical decision; quality controls enter before interpretation, and

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uncertain or threshold-level findings are directed to a validated reference method.

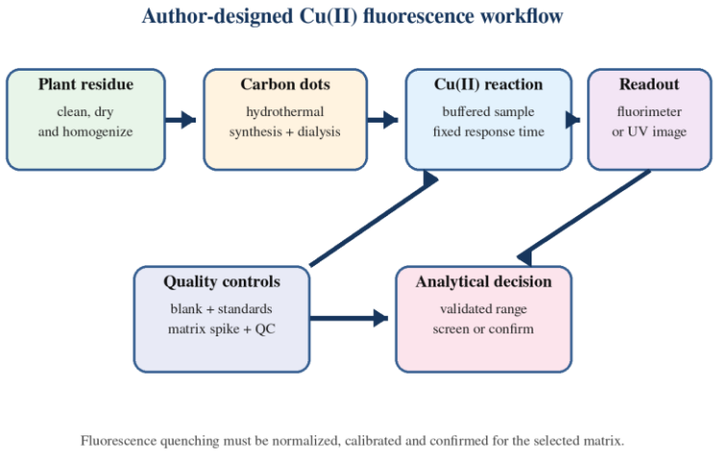

Figure 1
Proposed Cu(II) workflow. Source: designed by the author

8. Proposed experimental procedure

Washed citrus peel is dried to constant mass, milled and dispersed in ultrapure water. Parallel batches are prepared without and with a defined nitrogen donor. Hydrothermal temperature and time are optimized by a factorial or response-surface design, after which suspensions are cooled, centrifuged, membrane-filtered and dialyzed to constant optical background. A Cu(II) stock is prepared from a certified standard. Carbon-dot concentration, buffer, pH, ionic strength, mixing ratio and reaction time are optimized sequentially, while excitation and emission maxima are determined experimentally. Unknown drinking-water samples are analyzed with a reagent blank, at least six calibration levels, a continuing calibration check and matrix spikes. Metal-containing residues are collected as hazardous waste.

9. Signal processing and calibration

The primary response is the normalized quenching fraction $Q = (F_0 - F)/F_0$. Standards and samples are measured at the same dot concentration, pH, temperature and elapsed time. Replicate wells are randomized to reduce drift, and blank subtraction occurs before normalization. The calibration range is selected from residuals, not only the correlation coefficient. Weighted regression is considered when variance increases with concentration. Limits of detection and quantification are estimated from blank variability and

slope, then verified experimentally near the proposed reporting limit. Portable UV-image analysis may use a fixed enclosure and locked exposure, but it requires device-specific calibration. Smartphone-integrated Cu(II) work shows the value of controlled digital processing [11], whereas dual-emission approaches offer internal referencing [3,8].

10. Validation, selectivity and quality assurance

Validation includes working range, precision, bias, recovery, selectivity, dilution integrity, batch reproducibility, stability and reference-method agreement. Challenges should include Fe(III), Fe(II), Zn(II), Pb(II), Cd(II), Hg(II), Ca(II), Mg(II), Na(I) and common anions, first individually and then in mixtures. Drinking-water variables—pH, alkalinity, hardness, residual disinfectant, natural organic matter, turbidity and colour—are tested at realistic combinations. A new carbon-dot batch is accepted only if its blank intensity, emission maximum, control response and fortified-sample recovery meet predefined limits. Representative samples are compared with ICP-OES, ICP-MS or AAS. Results near an action threshold are reported as screening findings until confirmed. The positive real-water studies in [1,2,5,7] justify validation, but cannot substitute for local matrix testing.

11. Discussion and conclusion

Plant-derived fluorescent carbon dots can unite renewable materials with rapid Cu(II) screening, but green origin does not guarantee selectivity or reproducibility. Precursor variability, molecular impurities, photobleaching and matrix-dependent quenching remain major risks. The proposed method addresses them through controlled batches, purification, mechanistic testing, normalized calibration and independent confirmation. Its strongest application is preliminary screening and analytical-chemistry research, with later adaptation to portable formats. Experimental work is required before presentation as a validated quantitative method.

References:

[1] Toprak, Y. E., et al. (2026). Sensitive detection of copper(II) ions in water using nitrogen-doped carbon quantum dots synthesized from pine cone lignin and lysine. ACS Omega, 11(25), 37790-37800. https://doi.org/10.1021/acsomega.6c02895
[2] Chen, C.-S., Lin, M.-W., & Wan, C.-F. (2026). Copper ion detection using green precursor-derived carbon dots in aqueous media. Chemosensors, 14(1), 21. https://doi.org/10.3390/chemosensors14010021

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[3] Sun, J., et al. (2025). A dual-emissive carbon dot-functionalized paper-based analytical device for copper ion detection in foods. Sensors and Actuators B: Chemical, 443, 138176. https://doi.org/10.1016/j.snb.2025.138176
[4] Venkatesan, G., & Sathiyan, G. (2025). Recent trends in use of plant-derived carbon dot-based fluorescent probes for heavy metal ion detection and their biological applications. Trends in Environmental Analytical Chemistry, 46, e00259. https://doi.org/10.1016/j.teac.2025.e00259
[5] El-Azazy, M., et al. (2024). Mandarin peels-derived carbon dots: A multifaceted fluorescent probe for Cu(II) detection in tap and drinking water samples. Nanomaterials, 14(20), 1666. https://doi.org/10.3390/nano14201666
[6] Su, J., Wu, L., Zhu, Y., Xiong, Z., & Zhao, L. (2024). Nitrogen-silicon co-doped carbon dots synthesized based on lemon peel for copper(II) detection via a dynamic quenching mechanism. Optical Materials, 155, 115800. https://doi.org/10.1016/j.optmat.2024.115800
[7] Ren, H., et al. (2024). Transforming bio-waste lignin into amine functionalized carbon quantum dots for selective detection of trace Cu2+ in aqueous system. International Journal of Biological Macromolecules, 273, 133118. https://doi.org/10.1016/j.ijbiomac.2024.133118
[8] Pan, Y., et al. (2024). Red dual-emissive carbon dots for Cu2+ selective detection and dynamical monitoring. ACS Applied Nano Materials, 7(9), 10731-10738. https://doi.org/10.1021/acsanm.4c01257
[9] Zhang, Y., et al. (2024). Bifunctional magnetic carbon dots for the rapid fluorescent detection and the efficient adsorptive removal of copper ion. Microchemical Journal, 206, 111424. https://doi.org/10.1016/j.microc.2024.111424
[10] Soni, H., et al. (2024). From structure to sensing: Molecular mechanistic insights into plant-derived carbon dots for heavy metal ion detection. Nanomaterials, 14(21), 1766. https://doi.org/10.3390/nano14211766
[11] Zhang, D., et al. (2023). Red-to-blue colorimetric probe based on biomass carbon dots for smartphone-integrated optosensing of Cu(II) and L-cysteine. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 290, 122285. https://doi.org/10.1016/j.saa.2022.122285
[12] Singh, P., et al. (2023). Assessment of biomass-derived carbon dots as highly sensitive and selective templates for the sensing of hazardous ions. Nanoscale, 15(40), 16241-16267. https://doi.org/10.1039/D3NR01966G