Research paper **P 42**

PORTABLE COLORIMETRIC DETECTION OF Hg^{2+} IN WATER USING ECO-FRIENDLY PAPER-BASED SENSOR

N. Radivojević[1], T. Terzić[1], S. Knežević Graovac[1], S. Graovac[2], V. Rajić[1], M. Milanković[1], N. Potkonjak[1], S. Weheabby[3], I. Pašti[4], T. Lazarević-Pašti[1] and V. Milanković[1]

[1]*Vinča Institute of Nuclear Sciences – National Institute of the Republic of Serbia, University of Belgrade, Mike Petrovića Alasa 12-14, 11351 Belgrade, Serbia*

[2]*Faculty of Physics, University of Belgrade, POB 44, 11001 Belgrade, Serbia*

[3]*Measurement and Sensor Technology, Chemnitz University of Technology, Chemnitz 09126, Germany (saddam.weheabby@etit.tu-chemnitz.de)*

[4]*University of Belgrade - Faculty of Physical Chemistry, Studentski Trg 12-16, 11158 Belgrade, Serbia*

DOI: 10.68725/FDSQ_WORKSHOP.2026.9.53

ABSTRACT

Mercury is among the most hazardous heavy metals in aquatic systems due to its toxicity, persistence, and bioaccumulation, posing significant risks to ecosystems and human health. This study presents a sustainable, and low-cost approach for Hg^{2+} detection based on green-synthesized silver nanoparticles (AgNPs). AgNPs were prepared using an ethanolic extract of *Juglans regia* as a natural reducing and stabilizing agent and immobilized onto filter paper to fabricate a portable colorimetric sensor for Hg^{2+} detection. The sensing mechanism is based on the specific interaction between Hg^{2+} and AgNPs, producing a distinct color change visible to the naked eye. The sensor exhibited a linear detection range from 1×10^{-3} to 1×10^{-8} mol dm^{-3}, with a limit of detection of 1.065×10^{-8} mol dm^{-3}. The proposed platform offers eco-friendly synthesis, low production cost, portability, and instrument-free operation, making it a promising candidate for rapid on-site monitoring of Hg^{2+} contamination in water.

INTRODUCTION

Mercury is one of the most toxic and persistent heavy metals in aquatic environments, posing serious risks to ecosystems and human health. Although conventional techniques such as ICP-MS and AAS provide excellent sensitivity, they require expensive instrumentation and laboratory facilities, limiting their use for rapid on-site monitoring [1]. Silver nanoparticles (AgNPs) have emerged as promising colorimetric probes due to their localized surface plasmon resonance response toward Hg^{2+}. Immobilization of AgNPs onto cellulose filter paper further enhances portability and ease of use, although many reported sensors rely on chemically synthesized nanoparticles [2]. In this work, AgNPs were green-synthesized using *Juglans regia* extract and immobilized onto filter

paper to fabricate a portable colorimetric sensor for Hg^{2+} detection. The proposed platform combines sustainable nanoparticle synthesis with a simple paper-based format, offering a sensitive, low-cost, and environmentally friendly approach for rapid mercury monitoring in water.

EXPERIMENTAL

AgNPs were synthesized via a green route using an ethanolic extract of *Juglans regia* as both reducing and stabilizing agent. The nanoparticles were characterized by UV–Vis, FTIR, SEM–EDX, XRD, DLS, zeta potential, and ICP-OES analyses. A paper-based sensing platform was fabricated by immersing filter paper in the AgNP suspension, followed by air drying. Colorimetric detection of Hg^{2+} was evaluated by exposing the AgNP-coated paper to Hg^{2+} solutions of different concentrations. Sensor selectivity was investigated against various potentially interfering metal ions and common inorganic anions. Color changes were quantified from digital images using a custom Python/OpenCV image-processing algorithm based on a yellow index derived from RGB values. Analytical performance was assessed in terms of linear range, limit of detection, limit of quantification, and recovery using Hg^{2+}-spiked tap water samples.

RESULTS AND DISCUSSION

Green synthesis using *Juglans regia* extract successfully produced silver nanoparticles, as confirmed by UV-Vis, FTIR, DLS, XRD, FESEM–EDX, ICP-OES, and zeta potential analyses. UV-Vis spectroscopy showed the characteristic LSPR band at 405 nm, while XRD confirmed the formation of crystalline face-centered cubic silver. FESEM revealed predominantly spherical nanoparticles with an average diameter of approximately 30 nm, and EDX verified Ag as the major elemental component. FTIR spectra indicated that plant-derived biomolecules acted as reducing and stabilizing agents, whereas DLS and zeta potential measurements confirmed the formation of a moderately stable colloidal suspension suitable for sensor fabrication.

The colloidal AgNPs responded to several metal ions, with Hg^{2+} producing the most pronounced color change. However, the colloidal system showed limited visual selectivity, particularly at low concentrations. To improve performance, AgNPs were immobilized onto filter paper (Figure 1), producing a stable sensing platform.

The paper-based sensor exhibited a distinct color change only in the presence of Hg^{2+}, while no visible response was observed for other tested metal ions or common inorganic anions, even at much higher concentrations, demonstrating excellent selectivity.

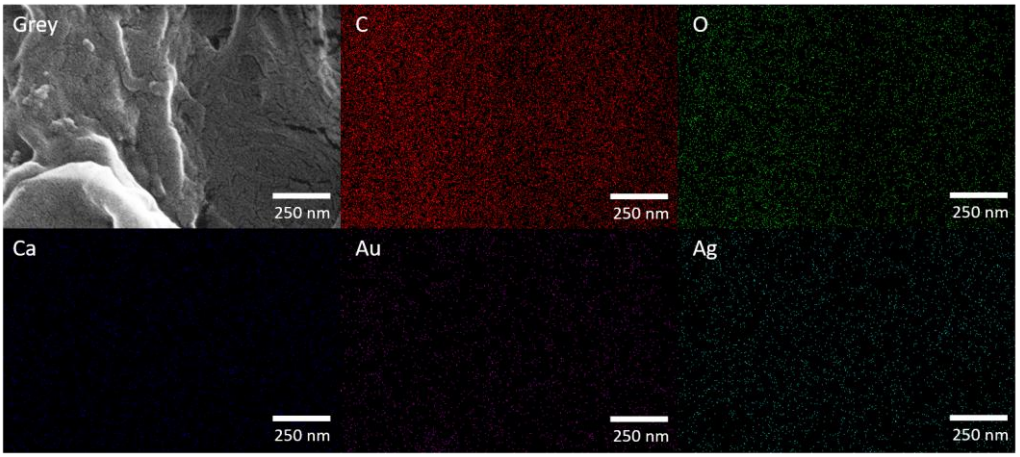


Figure 1. FESEM micrograph (150000 × magnification) and corresponding EDX elemental mapping of AgNPs@FP

The AgNPs@FP sensor showed a clear concentration-dependent color change over the Hg^{2+} concentration range of $1 \times 10^{-8} – 1 \times 10^{-3}$ mol dm^{-3} (Figure 2). Image analysis based on the yellow index produced a linear calibration curve with a LOD of 1.065×10^{-8} mol dm^{-3} and an LOQ of 3.263×10^{-8} mol dm^{-3}, enabling reliable nanomolar detection without sophisticated instrumentation.

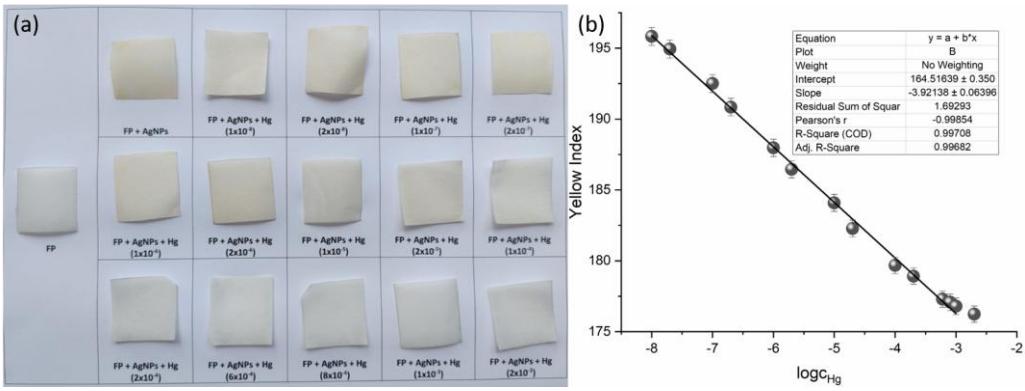


Figure 2. (a) Visual response of AgNPs@FP synthesized using *Juglans regia* extract, after exposure to increasing concentrations of Hg^{2+} (from 1×10^{-8} to 2×10^{-3} mol dm^{-3}); (b) Calibration curve showing the linear dependence of yellow index on the logarithm of Hg^{2+} concentration.

The applicability of the sensor was evaluated using Hg^{2+}-spiked tap water. Recoveries ranged from 96% to 102%, confirming excellent accuracy and negligible matrix effects without any sample pretreatment. These results demonstrate the suitability of the proposed paper-based sensor for rapid environmental monitoring (Table 1).

Table 1. Detection of Hg^{2+} in spiked tap water samples using AgNPs@FP sensor.

Spiked concentration (mol dm^{-3})	Found concentration (mol dm^{-3})	Recovery (%)
1.0×10^{-3}	$(9.8 \pm 0.1)\times10^{-4}$	98 ± 1
1.0×10^{-4}	$(1.02 \pm 0.04)\times10^{-4}$	102 ± 4
1.0×10^{-5}	$(9.9 \pm 0.4)\times10^{-6}$	99 ± 4
1.0×10^{-6}	$(1.01 \pm 0.03)\times10^{-6}$	101 ± 3
1.0×10^{-7}	$(9.7 \pm 0.2)\times10^{-8}$	97 ± 2
1.0×10^{-8}	$(9.6 \pm 0.5)\times10^{-9}$	96 ± 5

CONCLUSION

This study demonstrates that green-synthesized silver nanoparticles obtained using *Juglans regia* extract can be successfully immobilized onto filter paper to create a portable and highly sensitive colorimetric sensor for Hg^{2+} detection. The developed platform enables nanomolar detection (LOD = 1.065×10^{-8} mol dm^{-3}) over a broad linear range without requiring sophisticated instrumentation. Combining plant-mediated synthesis with a simple paper-based format provides a sustainable, low-cost, and user-friendly approach for rapid on-site monitoring of mercury in water.

Acknowledgement

This work was funded by the Serbian Ministry of Science, Technological Development, and Innovations (grant numbers 451-03-34/2026-03/200146, 451-03-33/2026-03/200017, and 451-03-33/2026-03/200162). The authors also acknowledge support from the Serbian Academy of Sciences and Arts (project no. F-49).

REFERENCES

[1] S. Ali, M. Mansha, N. Baig, S. A. Khan, The Chemical Record, 2022, 22, 7.

[2] S. Wang, W.-J. Chen, A. Du, Y. Kou, X. Xu, D. Hu, Z. Lu, Advanced Composites and Hybrid Materials, 2025, 8, 3.