Electronic Supplementary Material (ESI) for RSC Advances.

Gingerol extract-stabilized silver nanoparticles and their applications: colorimetric and machine learning-based sensing of Hg (II) and antibacterial properties

Kittiya Plaeyao[a], Ratchaneekorn Kampangta[a], Yuparat Korkokklang[a], Chanon Talodthaisong[a], Apichart Saenchoopa[a], Saengrawee Thammawithan[b], Krailikhit Latpala[c], Rina Patramanon[b], Navaphun Kayunkid[d], Sirinan Kulchat*[a]

[a]*Materials Chemistry Research Center, Department of Chemistry and Center of Excellence for Innovation in Chemistry, Faculty of Science, Khon Kaen University, Khon Kaen, 40002, Thailand.*
[b]*Department of Biochemistry, Faculty of Science, Khon Kaen University, Khon Kaen, 40002, Thailand.*
[c]*Department of Mathematics, Faculty of Science, Khon Kaen University, Khon Kaen, 40002, Thailand.*
[d]*College of Materials Innovation and Technology, King Mongkut's Institute of Technology Ladkrabang, Ladkrabang, Bangkok 10520, Thailand*
*Email: sirikul@kku.ac.th

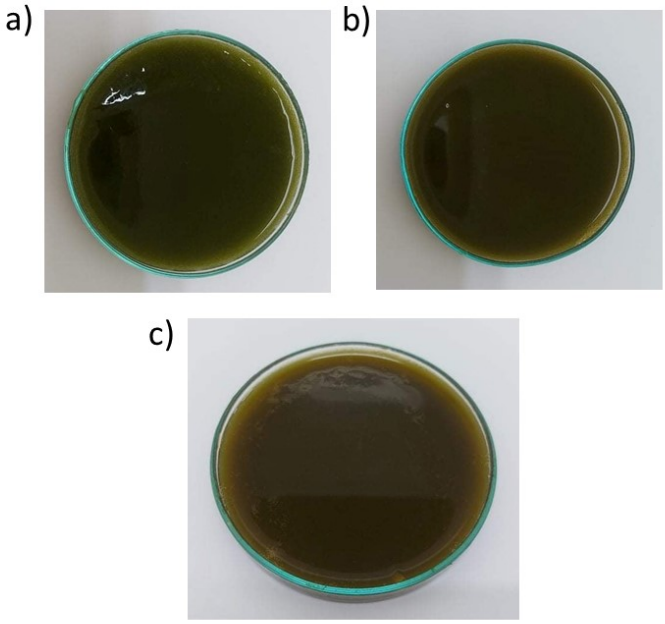

Fig. S1 The Gin-AgNPs hydrogel from *Cissampelos pareira L,* a) using DI water, 2) 15 µM of Gin-AgNPs solution and c) 25 µM of Gin-AgNPs solution.

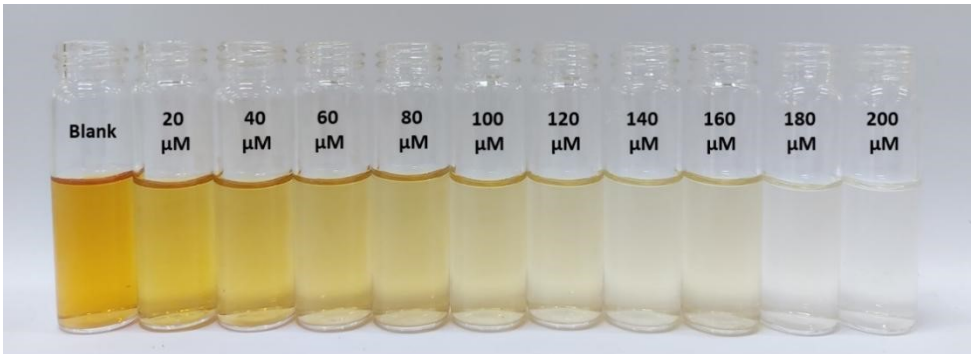

Fig. S2 The Gin-AnNPs solution with different concentrations of Hg^{2+} ranging from 0 μM – 200 μM (from left to right: 0, 20, 40, 60, 80, 100, 120, 140, 160, 180 and 200 µM where blank refers to 0 µM).

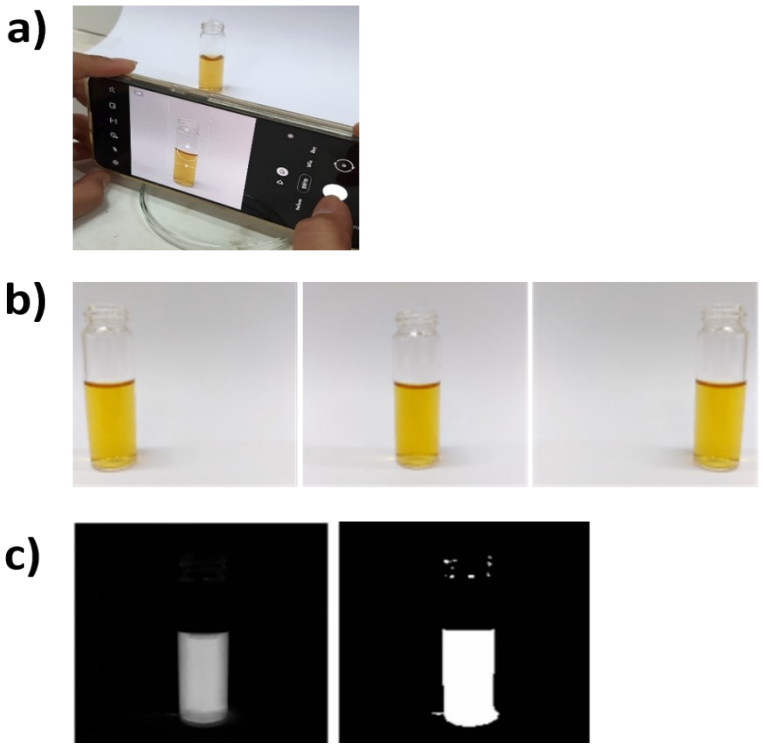

Figure. S3 a) setting the camera and taking the pictures for creating the database, b) the different shooting positions at different angles for one concentration, c) image with extracted feature (left) and its binary image (right).

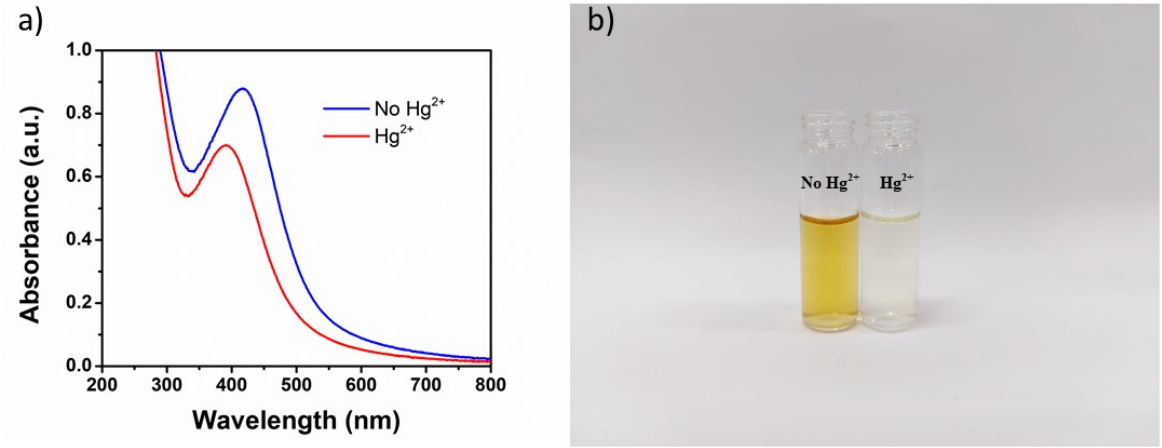

Fig. S4 a) UV-vis spectra of Gin-AgNPs and Gin-AgNPs+Hg^{2+}, b) the respective image of Gin-AgNPs and Gin-AgNPs with added Hg^{2+} 200 µM.

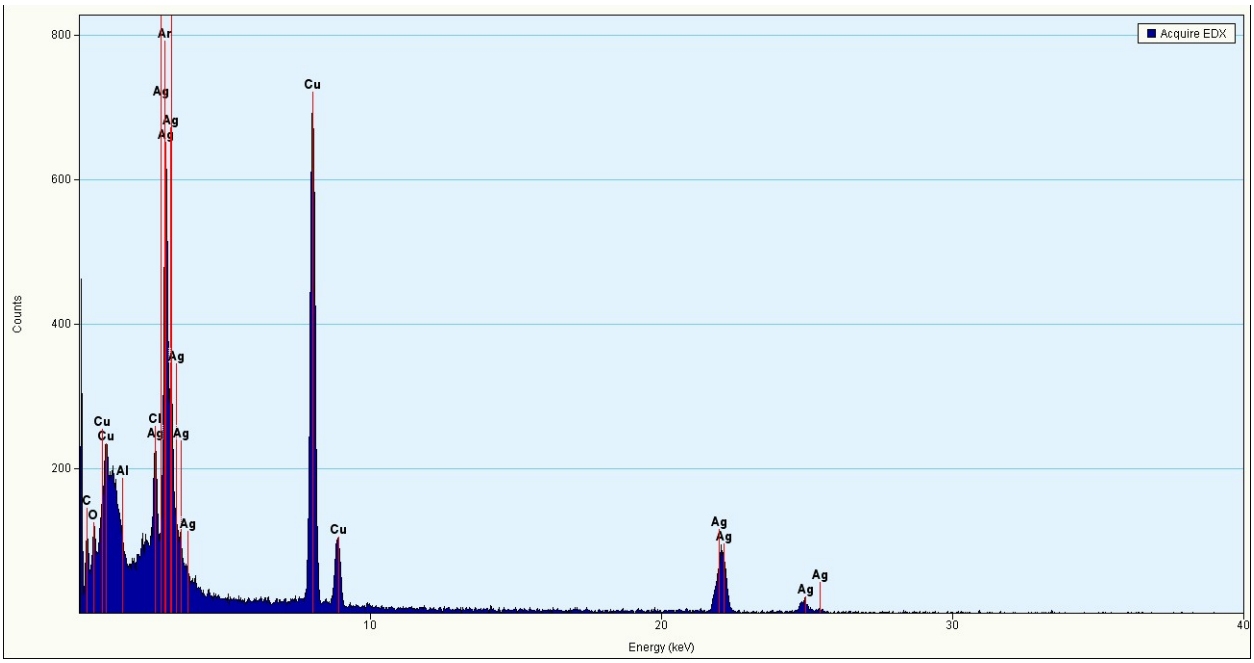

Fig. S5 EDX images of Gin-AgNPs.

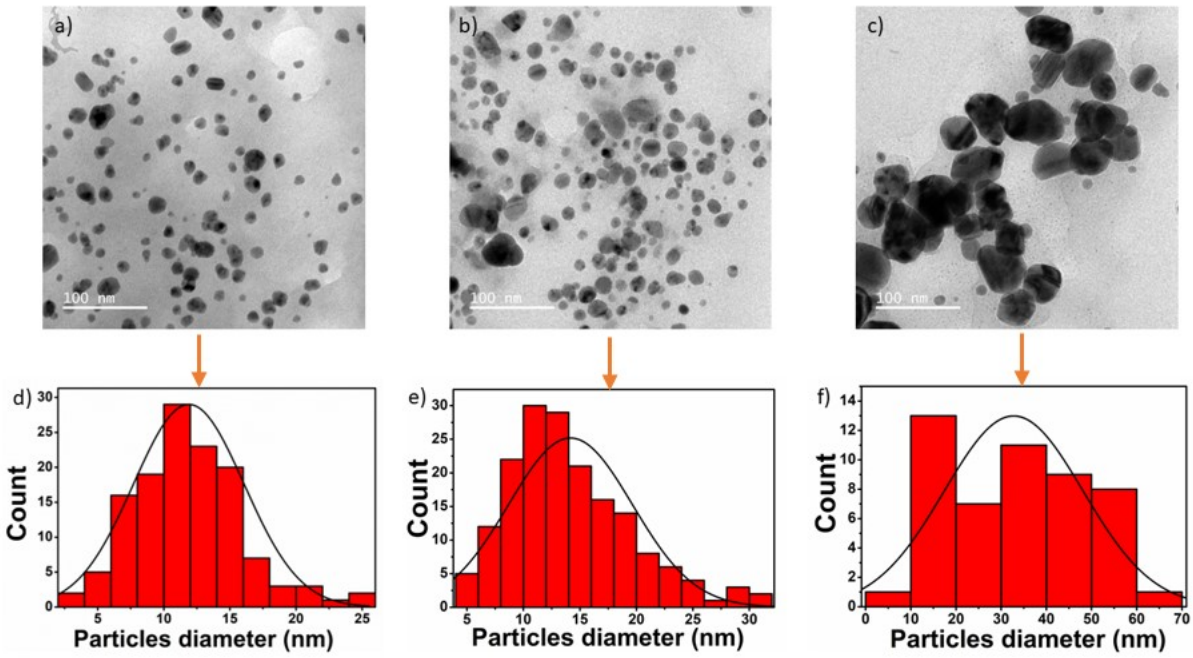

Fig. S6 TEM images of a) Gin-AgNPs, b) Gin-AgNPs+buffer (pH 8) and c) Gin-AgNPs+buffer (pH8) +Hg^{2+} and the size distribution plots of d) Gin-AgNPs (11.89 ± 4.17 nm (n=130)), e) Gin-AgNPs+buffer (pH 8) (14.17 ± 5.46 nm (n=150)), and f) Gin-AgNPs+buffer (pH8) +Hg^{2+} (35.55 ± 11.12 nm (n=50)).

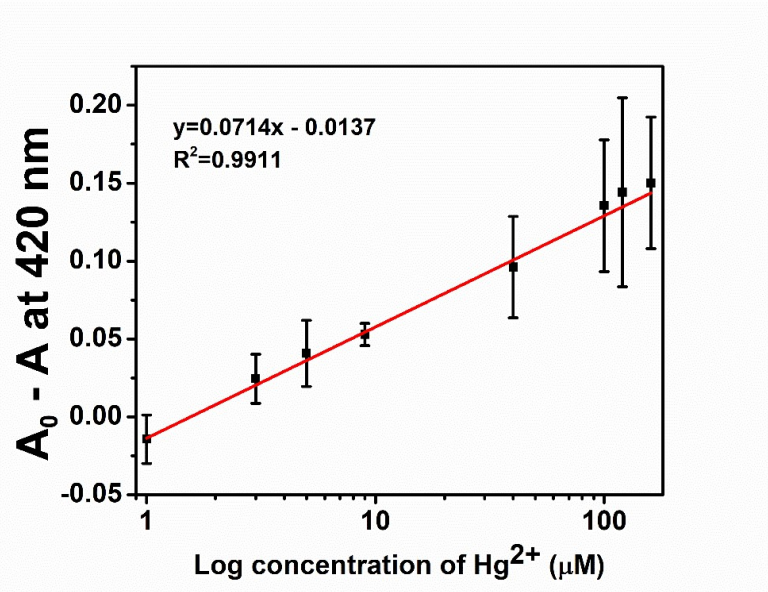

Fig. S7 The absorbance ratio (A0-A) at 420 nm as a function of Hg^{2+} concentration, a linear equation of (A0-A) and the correlation coefficient squared (R^2) for calculating the concentration of Hg^{2+} in real sampled water.

Table S1: The estimated concentrations for the data set 1

Concentrations (μM)	Position of test tube		
	on the left	in the middle	on the right
0	0	0	0
20	20.34	20	20
40	40.30	40	40
60	60.68	60	60
80	80	80	79.96
100	100	100	99.63
120	120.01	120	120
140	140	140.31	140
160	160	159.96	160
180	180	180.20	180
200	200	200	200

Table S2*:* The estimated concentrations for the data set 2

Concentration (μM)	Estimation (μM)
0	2.27
20	17.42
40	43.85
60	60.00
80	75.77

100	96.83
120	110.60
140	135.27
160	155.87
180	176.63
200	199.70

Table S3*:* The estimated concentrations for the data set 3

Concentration (μM)	Estimation (μM)
70	60.00
110	93.96
150	140.18
190	183.04

Table S4*:* Comparison of the performance of several methods for Hg2+ detection in water

Methods	Materials	Linear range (μM)	The limit of detection (μM)	Ref.
Electrochemistry	Graphene oxide-ionic liquid composites-gold nanoparticles	0.0001-0.1	0.00003	[1]
	Bis(indolyl)methane/mesoporous carbon nanofiber/Nafion/glassy carbon electrode	0.005-0.5	0.0003	[2]
	Polypyrrole-coated nanospherical platinum	0.005-0.5	0.00027	[3]
	Gold nanoparticles-thiol-functionalized reduced graphene oxide coated electrochemical sensor	1-10	0.2	[4]
	FeOOH-modified nanoporous gold microelectrode	0.02-2.2	0.0078	[5]
Fluorescence	Turn-on fluorescent sensor based on graphene oxide and DNA aptamers	0.0005-0.05	0.00017	[6]
	Gold nanoclusters with bovine serum albumin and bromelain	0.00075-5.0	0.0003	[7]

	Fluorescent Ag clusters via a protein-directed approach	0.01-5	0.01	[8]
	Carbon dots-based fluorescent probe	0-80	0.201	[9]
	MoS_2 nanosheets/DNA/silicon dot nanoassembly	0-1.0	0.00086	[10]
Colorimetric	Magnetic nanocomposite (Fe3O4@ZIF-67)	0-0.03	0.00036	[11]
	Thiamine-functionalized silver nanoparticles	0.01-5	0.005	[12]
	Cysteine-modified Au-Ag core-shell nanorods	1-60	0.273	[13]
	Ag_3PO_4 microcubes	0.1-7.0	0.02	[14]
	Paper-based cation-selective optode sensor containing benzothiazole calix [4]arene	0.574-50	0.574	[15]
	Ginger silver nanoparticles (Gin-AgNPs)	3-160	1.46	This work

References

1 N. Zhou, J. Li, H. Chen, C. Liao and L. Chen, *Analyst*, 2013, **138**, 1091–1097.

2 Y. Liao, Q. Li, N. Wang and S. Shao, *Sensors and Actuators B: Chemical*, 2015, **215**, 592–597.

3 M. Mahmoudian, W. Basirun and Y. Alias, *RSC advances*, 2016, **6**, 36459–36466.

4 N. R. Devi, M. Sasidharan and A. K. Sundramoorthy, *Journal of the Electrochemical Society*, 2018, **165**, B3046–B3053.

5 Z. Liu, E. Puumala and A. Chen, *Sensors and Actuators B: Chemical*, 2019, **287**, 517–525.

6 H. Guo, J. Li, Y. Li, D. Wu, H. Ma, Q. Wei and B. Du, *New Journal of Chemistry*, 2018, **42**, 11147–11152.

7 J. R. Bhamore, S. Jha, H. Basu, R. K. Singhal, Z. Murthy and S. K. Kailasa, *Analytical and bioanalytical chemistry*, 2018, **410**, 2781–2791.

8 C. Guo and J. Irudayaraj, *Analytical chemistry*, 2011, **83**, 2883–2889.

9 J. He, H. Zhang, J. Zou, Y. Liu, J. Zhuang, Y. Xiao and B. Lei, *Biosensors and Bioelectronics*, 2016, **79**, 531–535.

10 K. Srinivasan, K. Subramanian, K. Murugan, G. Benelli and K. Dinakaran, *Environmental Science and Pollution Research*, 2018, **25**, 10567–10576.

11 A. A. B. Christus, P. Panneerselvam, A. Ravikumar, N. Morad and S. Sivanesan, *Journal of Photochemistry and Photobiology A: Chemistry*, 2018, **364**, 715–724.

12 U. Khan, A. Niaz, A. Shah, M. I. Zaman, M. A. Zia, F. J. Iftikhar, J. Nisar, M. N. Ahmed, M. S. Akhter and A. H. Shah, *New Journal of Chemistry*, 2018, **42**, 528–534.

13 J. Zhu, B. Zhao, Y. Qi, J.-J. Li, X. Li and J.-W. Zhao, *Sensors and Actuators B: Chemical*, 2018, **255**, 2927–2935.

14 Y. Zhang, P. Ju, L. Sun, Z. Wang, X. Zhai, F. Jiang and C. Sun, *Microchimica Acta*, 2020, **187**, 1–14.

15 M. Phichi, A. Imyim, T. Tuntulani and W. Aeungmaitrepirom, *Analytica Chimica Acta*, 2020, **1104**, 147–155.