Environ. Eng. Res. 2024; 29(5): 230636
https://doi.org/10.4491/eer.2023.636

Supplementary Materials

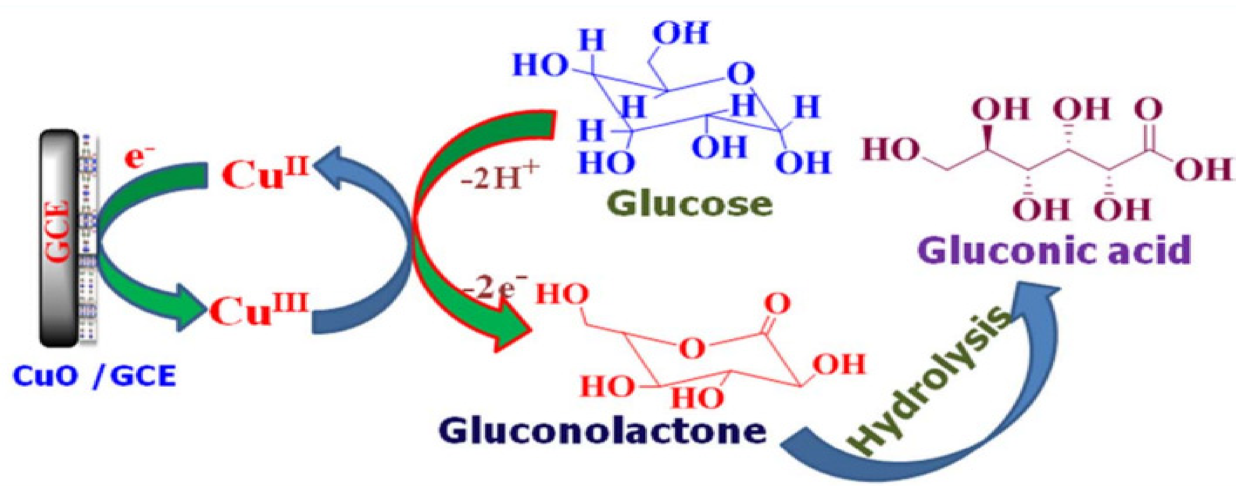

Fig. S1. Electrochemical oxidation of glucose on MOF modified GCE [1]

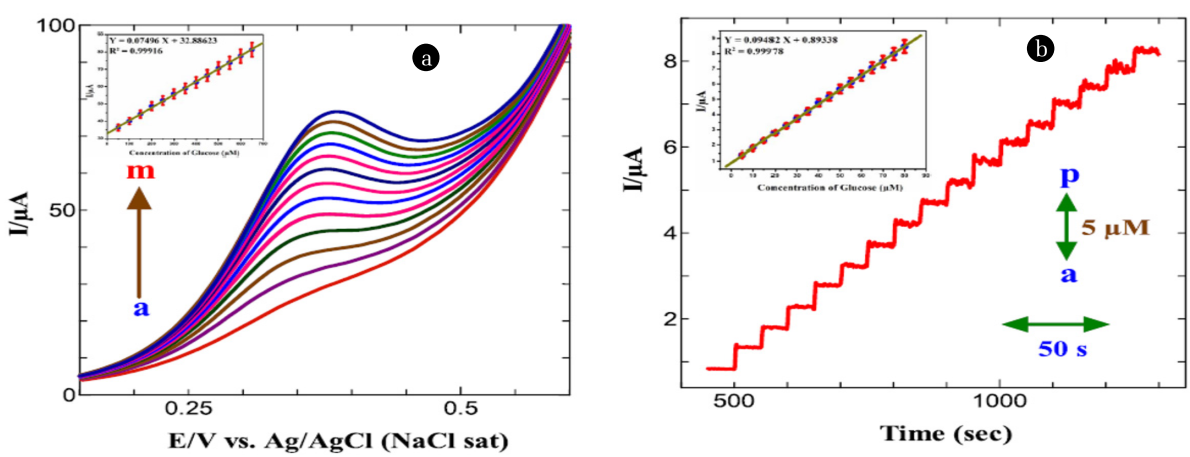

Fig. S2. (A) DPVs obtained for 50 μM of glucose at CuO modified GC electrode in 0.1 M NaOH. Each addition of glucose increased the concentration by 50 μM (a–m) (B) The amperometric i-t curve for glucose produced at a GC/CuO electrode in 0.10 M NaOH [1].

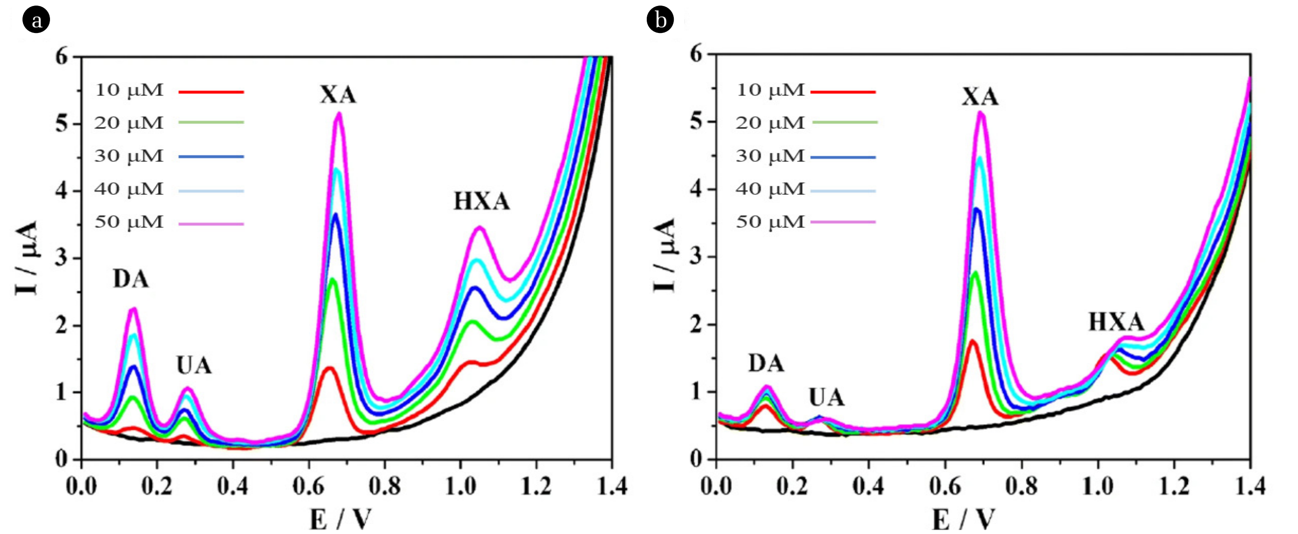

Fig. S3. DPV curves of simultaneous determination of (a) Xanthine (XA) with different concentration (10, 20, 30,40, 50 μM) in presence of 10 μM Dopamine (DA), Uric acid (UA) and Hypoxanthine (HXA) (b) Xanthine (XA) with 10 μM concentration in presence of 10 μM Dopamine (DA), Uric acid (UA) and Hypoxanthine (HXA) [2].

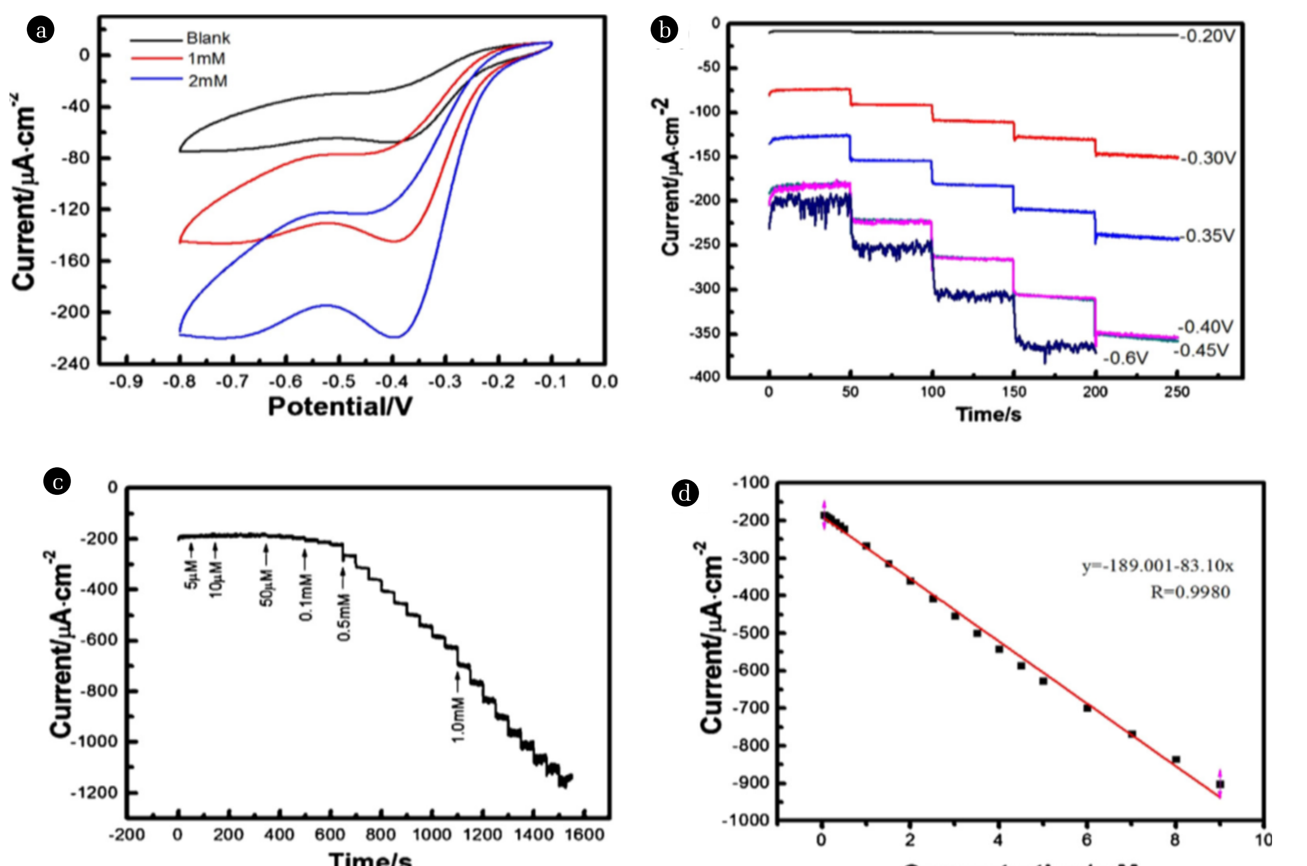

Fig. S4. (a) Voltammograms and amperometric response of Co-MOF in the absence and presence of 1 and 2 mM H_2O_2 in 0.1 M NaOH solution. (b) and (c) Amperometric response of the Co-MOF modified GCE at potential range −0.4 to −0.6V. (d) Calibration curve of amperometric response [3].

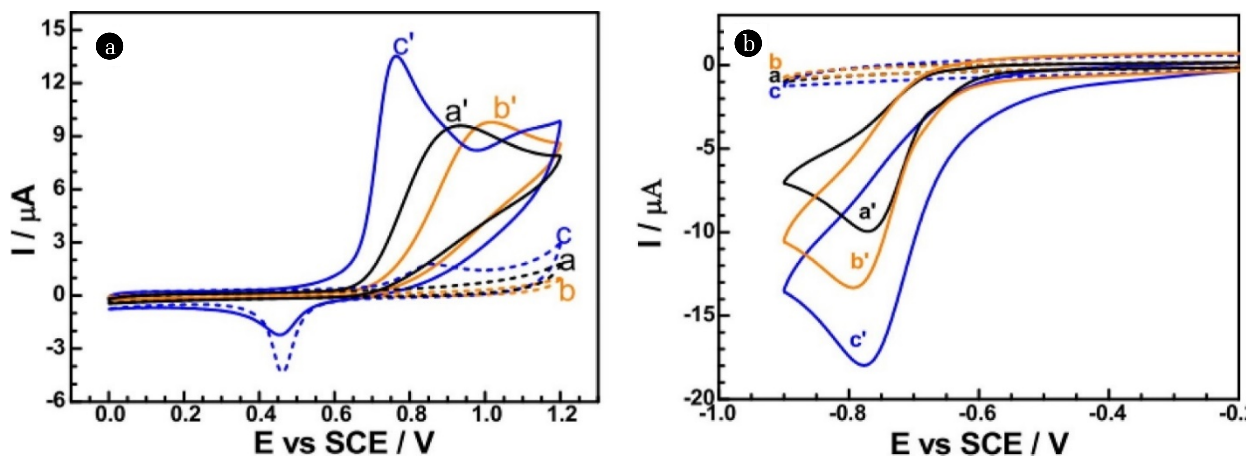

Fig. S5. Cyclic Voltammogram of (a) Nitrite (a, b, c are peaks obtained in the absence of nitrite at 0.1 M PB; a′, b′, c′ are peaks obtained in the presence of nitrite at 0.1 M PB) and (b) Nitrobenzene (a, b, c are peaks obtained in the absence of nitrobenzene at 0.1 M PB; a′, b′, c′ are peaks obtained in the presence of nitrobenzene at 0.1 M PB) induced by MOF-5/Au NPs modified GCE [4].

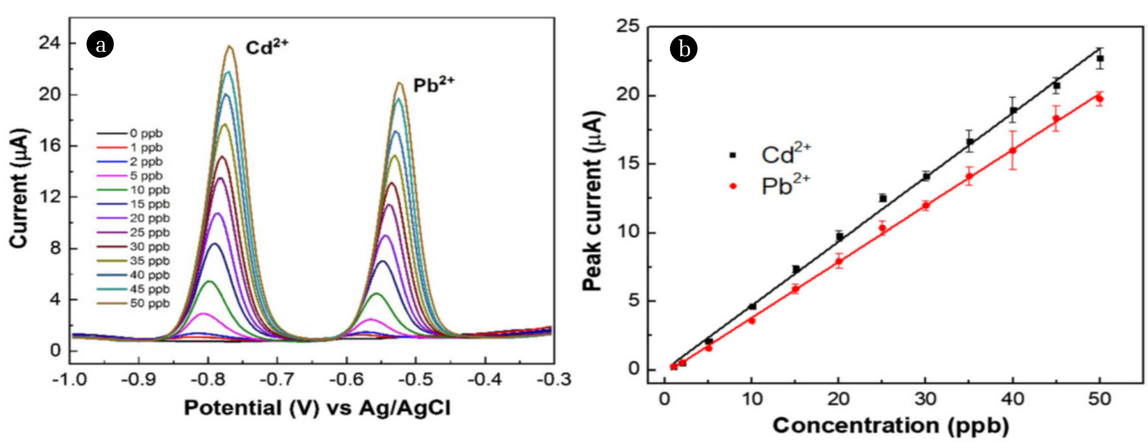

Fig. S6. (a) The simultaneous voltammograms of Cd^{2+} and Pb^{2+} (b) the corresponding calibration curve using Ytterbium-based MOF [5].

Table S1. Electrochemical sensing of several biomolecules using various MOF modified electrodes.

Electrode type	Analyte	MOF	MOF composite	Work potential (V)	pH	LOD	Linear range (10^{-6} mol/L)	Real sample	References
NPCP	Leuteoline	ZIF-67	CuCo@NPCP	0.10	7.0	0.080 nM	0.20–2.50	Human vaccine	[6]
G.C.E.	Dopamine	ZIF-8	ZIF-8@G	0.30	7.0	1.00 μM	3.0–1.00	Cow vaccine	[7]
G.C.E.	L-Cysteine	HKUST-1	Au-SH-SiO_2@Cu-MOF	0.40	5.0	0.0080 μM	0.02–300	-	[8]
G.C.E.	Ascorbic acid	HKUST-1	HKUST-1@GO	-0.02	7.0	20.0 nM	0.50–6965	-	[9]
G.C.E	Catechol	MIL-101	MIL-101 (Cr)@rGO	-	7.0	4.00 μM	10.0–1400	Lake	[10]
G.C.E	Xanthine	MIL-101	Pt-NPs@MIL-101	0.280	7.0	0.420 μM	0.50–162	Human vaccine	[11]
G.C.E	17β-estradiol	MIL-53	MIP-Pb/MIL-53@CNT	0.210	3.0	0.00615 pM	0.010–1000	Domestic	[12]
G.C.E	Glucose	GOD/Cu	Hemin	-0.25	7.0	2.73 μM	9.10–36.0	Human Serum	[13]
G.C.E	Glucose	ZIF-8@GOx	GO	0.4	7.4	0.05 mM	1–10	Calf Serum	[14]
G.C.E	Glucose	ZIF-8	Fe_3O_4/PPy/GOx	0.6	7	0.333 μM	1–2	Human Serum	[15]
G.C.E	Glucose	Cu-MOF	MWCNTs	0.55	7	0.4 μM	0.5–11.84	Human Serum	[16]
G.C.E	Dopamine	UiO-66-NH_2	CNTs	-0.4	7	15 nM	0.03–2	Human Serum	[17]
G.C.E	Urea	Ni-MOF	MWCNT/ITO	0.45		3.0 μM	10–1120	Urine	[18]

Table S2. MOF-modified carbon-based electrodes used for amperometry measurement of H_2O_2 in various samples.

Electrode type	MOF	Reduction potential (V)	pH	LOD	Linear range (10^{-6} mol/L)	Real sample	Ref.
CPE	Ni-MOF	−0.250	13	0.00090 mM	0.0040–60	Cleaning soln.	[19]
GCE	Y1-4-NDC-MOF	−0.50	7	0.430 μM	04.0–11000	A549 cells	[20]
GCE	Ce1-xTbx-MOF	0.750	7	7.70 μM	0.10–4.2	-	[21]
GCE	$[Cu(adp)(BIB)(H_2O)]n$	–	13	0.0680 μM	0.100–2.750	-	[22]
GCE	$Cu(btec)_{0.5}DMF$	−0.20	6.5	0.8650 μM	5.0–8000	-	[23]
GCE	$\{[Cu_2(bep)(ada)_2]H_2O\}_n$	−0.45	13	0.014 μM	0.05–3	-	[24]
CPE	Cu-MOF	−0.2	7.2	1.00 μM	1.0–0.99	-	[25]
GCE	HKUST-1	−0.4	7	0.49 μM	1.0–5.6	Raw 264.7 cells	[26]
GCE	Zn-MOF	−0.80	7.2	67 nM	1–5	Milk	[27]
CPE	Co-MOF	−0.30	7.2	0.50 μM	1.0–823	-	[28]
GCE	MIL-53-Cr(III)	−0.307	13	3.520 μM	25.0–500	Human vaccine	[29]
GCE	Ni-MOF/CNTs	0.5	13	2.1 μM	10–5.600	-	[30]
GCE	$AuNPs-NH_2/Cu-MOF$	–0.15	7.4	1.2 μM	5–850	HeLa cells	[31]
GCE	ZIF-67	–0.05	7	0.11 μM	1.86–1050	-	[32]
GCE	Ag-Bi–BDC (s) MOF	–0.4	7	0.02 μM	10–5000	THP-1	[33]
GCE	2D Co-MOF	0.25	12	0.69 μM	0.5–832	-	[34]
CPE	AP-Ni-MOF	–0.25	7	0.9 μM	4–60000	Lens cleaning solution	[35]

Table S3. MOFs for detecting organic contaminants in water.

Electrode type	Analyte	MOF	Working Potential (V)	pH	LOD	Linear range (10^{-6} mol/L)	Real sample	Reference
GCE	Nitrobenzene	MOF-5	−0.790	7	15.3 μM	20.0–500	-	[36]
GCE	Nitrite	MOF-525	0.90	8	2.10 μM	20.0–800	-	[37]
CPE	Nitrite	Cu-MOF	0.9	7.2	30 nM	50–712	Lake water	[38]
GCE	Hydrazine	Co-MOF	0.20	-	–	5.0–630	-	[39]
GCE	Dihydroxybenzene	HKUST-1	N/r	7	0.590 μM	1.0–1000	Domestic	[40]
GCE	Hydroxylamine	MMPF-6	0.350	7	0.004 μM	1–20	Domestic	[41]
GCE	BPA	Ce-MOF	0.520	7	02.0 nM	0.005–5.00	Milk	[42]
GCE	Paracetamol	HKUST-1	−0.060	6	0.01–100 μM	0.01–100.0	Commercial tabs	[43]
GCE	Metformin	HKUST-1	0.6	13	5.0–25 μM	5–25.0	Commercial tabs	[44]
GCE	Chloramphenicol	IRMOF-8	−0.10	7.5	0.010–1.0 μM	0.01–1.0	Honey	[45]
GCE	Diphenyl ether	MAC-ZIF-8	–0.4	7	0.46 μM	0–114	Apricot	[46]
GE	Ochratoxin A	AgPt/PCN-223-Fe	–0.6	6	20–2000	14	Red wine	[47]
GCE	Paraoxon	Ce/UiO-66@MWCNTs	0.2	7.5	0.01–150	0.004	Spinach	[48]

Table S4. Examples of carbon-based electrodes modified with MOFs for measuring the concentration of heavy metals in water using stripping voltammetry.

Electrode type	Analyte	M.O.F.	Penetration Potential (V)	pH	L.O.D.	Linear Range (10^{-6} mol/L)	Real sample	Ref
CPE	Cd^{2+}	$[Zn_2(NH_2\text{-}BDC)_2(4\text{-}bpdh)]\cdot 3DMF$	-1.0	3	0.2 μM	0.7–120	Tap water	[49]
GCE	Zn^{2+}	BiCux-ANPs@CF/SPCE	-1.2	4.5	35 μM	150–600	Urine	[50]
CPE	Pb^{2+}	MOF-5	-0.9	5	4.9 μM	10–1000	Tap water	[51]
GCE	Hg^{2+}	3DGO/UiO-66-NH_2	-1.1	7.4	3.1 μM	0.01–3.5	Rice and honey sample	[52]
GCE	Cu^{2+}	Co-TMC4R-BDC	-1.3	5	0.067 μM	0.25–9	Lake water	[53]
GCE	Cu^{2+}	Yb-MOF	-1.1	4.5	1.6 μM	0–50	River water	[54]
GCE	Hg^{2+}	UiO-66-NH_2/GaOOH	-1.0	6	0.006 μM	0.10–0.45	Waste water	[55]
GCE	Pb^{2+}	NH_2-$CU_3(BTC)_2$	-1.0	4.5	5.0 μM	10–500	Powder milk	[56]
GCE	Hg^{2+}	Fe1Co1	-1.0	5	0.0078 μM	0.1–1.1	River water	[57]
CPE	Cu^{2+}	MIL -47	-1.10	4.5	0.087 μM	1–10	Lake water	[58]
GCE	Hg^{2+}	ZJU -27	-0.58	5	0.0013 μM	0.5–2	Lake water	[59]
GCE	Pb^{2+}	ZIF-8	-1.2	4.7	4.16 μM	12–100	–	[60]
GCE	Cu^{2+}	GA -UiO -66 -NH_2	-1.3	5	0.008 μM	0.01–1.6	Vegetable	[61]
GPE	Cu^{2+}	Ca -MOF	-0.2	4.5	1.4 μM	10–60	Waste water	[62]
GCE	Hg^{2+}	ZIF -67/EG	-0.80	5	0.00129 μM	0.5–3	Waste water	[63]
CPE	Pb^{2+}	MOF-235	-	N/r	50 μM	–	Tap water	[64]
KSC	Hg^{2+}	Zr -DMBD MOF	-0.8	6	0.05 μM	0.25–3.5	River water	[65]
GCE	Pb^{2+}	Bi/Bi_2O_3@C	-0.9	5	6.3 nM	37.5–2	River water	[66]

References

1. Arul P, John S. Electrodeposition of CuO from Cu-MOF on glassy carbon electrode: A non-enzymatic sensor for glucose. *J. Electroanal. Chem*. 2017;799. doi:10.1016/j.jelechem.2017.05.041.
2. Zhang L, Li S, Xin J, et al. A non-enzymatic voltammetric xanthine sensor based on the use of platinum nanoparticles loaded with a metal-organic framework of type MIL-101(Cr). Application to simultaneous detection of dopamine, uric acid, xanthine and hypoxanthine. *Microchim. Acta*. 2018;186:9. doi:10.1007/s00604-018-3128-4.
3. Jung D, Yang DA, Kim J, Ahn W. Facile synthesis of MOF-177 by a sonochemical method using 1-methyl-2-pyrrolidinone as a solvent. *Dalton Trans*. 2010;39:2883–2887. doi:10.1039/B925088C.
4. Yadav D, Ganesan V, Sonkar PK, Gupta R., Rastogi P. Electrochemical investigation of gold nanoparticles incorporated zinc based metal-organic framework for selective recognition of nitrite and nitrobenzene. *Electrochim. Acta*. 2016;200:276–282. doi:10.1016/j.electacta.2016.03.092.
5. Cruz-Navarro JA, Hernandez-Garcia F, Alvarez Romero GA. Novel applications of metal-organic frameworks (MOFs) as redox-active materials for elaboration of carbon-based electrodes with electroanalytical uses. *Coord. Chem. Rev*. 2020;412:213263. doi:10.1016/j.ccr.2020.213263.
6. Feng X, Yin X, Bo X, Guo L. An ultrasensitive luteolin sensor based on MOFs derived CuCo coated nitrogen-doped porous carbon polyhedron. *Sens. Actuators B Chem*. 2019;281:730–738. doi:10.1016/j.snb.2018.11.010.
7. Zheng YY, Li CX, Ding XT, et al. Detection of dopamine at graphene-ZIF-8 nanocomposite modified electrode. *Chin. Chem. Lett*. 2017;28:1473–1478. doi:10.1016/j.cclet.2017.03.014.
8. Hosseini H, Ahmar H, Dehghani A, Bagheri A, Tadjarodi A, Fakhari A. A novel electrochemical sensor based on metal-organic framework for electro-catalytic oxidation of L-cysteine. *Biosens. Bioelectron*. 2013;42:426–429. doi:10.1016/j.bios.2012.09.062.
9. Yang J, Zhao F, Zeng B. One-step synthesis of a copper-based metal–organic framework–graphene nanocomposite with enhanced electrocatalytic activity. *RSC Adv*. 2015;5:22060–22065. doi:10.1039/C4RA16950F.
10. Wang H, Hu Q, Meng Y, et al. Efficient detection of hazardous catechol and hydroquinone with MOF-rGO modified carbon paste electrode. *J. Hazard. Mater*. 2018;353:151–157. doi:10.1016/j.jhazmat.2018.02.029.
11. Zhang L, Li S, Xin J, et al. A non-enzymatic voltammetric xanthine sensor based on the use of platinum nanoparticles loaded with a metal-organic framework of type MIL-101(Cr). Application to simultaneous detection of dopamine, uric acid, xanthine and hypoxanthine. *Microchim. Acta*. 2018;186:9. doi:10.1007/s00604-018-3128-4.
12. Duan D, Si X, Ding Y, et al. A novel molecularly imprinted electrochemical sensor based on double sensitization by MOF/CNTs and Prussian blue for detection of 17β-estradiol. *Bioelectrochemistry* 2019;129:211–217. doi:10.1016/j.bioelechem.2019.04.014.
13. He J, Yang H, Zhang Y, et al. Smart Nanocomposites of Cu-Hemin Metal-Organic Frameworks for Electrochemical Glucose Biosensing.

Sci. Rep. 2016;6:36637. doi:10.1038/srep36637.
14. Singh R, Musameh M, Gao Y, Ozcelik B, Mulet X, Doherty C. Stable MOF@enzyme composites for electrochemical biosensing devices. *J. Mater. Chem. C*. 2021;9:7677–7688. doi:10.1039/D1TC00407G.
15. Hou C, Zhao D, Wang Y, Zhang S, Li S. Preparation of magnetic Fe_3O_4/PPy@ZIF-8 nanocomposite for glucose oxidase immobilization and used as glucose electrochemical biosensor. *J. Electroanal. Chem*. 2018;822:50–56. doi:10.1016/j.jelechem.2018.04.067.
16. Shahrokhian S, Sanati EK, Hosseini H. Direct growth of metal-organic frameworks thin film arrays on glassy carbon electrode based on rapid conversion step mediated by copper clusters and hydroxide nanotubes for fabrication of a high performance non-enzymatic glucose sensing platform. *Biosens. Bioelectron*. 2018;112:100–107. doi:10.1016/j.bios.2018.04.039.
17. Li Y, Shen Y, Zhang Y, et al. A UiO-66-NH_2/carbon nanotube nanocomposite for simultaneous sensing of dopamine and acetaminophen. *Anal. Chim. Acta*. 2021;1158:338419. doi:10.1016/j.aca.2021.338419.
18. Tran TQN, Das G, Yoon HH. Nickel-metal organic framework/MWCNT composite electrode for non-enzymatic urea detection. *Sens. Actuators B Chem*. 2017;243:78–83. doi:10.1016/j.snb.2016.11.126.
19. Sherino B, Mohamad S, Abdul Halim SN, Abdul Manan N. Electrochemical detection of hydrogen peroxide on a new microporous Ni–metal organic framework material-carbon paste electrode. *Sens. Actuators B Chem*. 2018;254:1148–1156. doi:10.1016/j.snb.2017.08.002.
20. Li C, Wu R, Zou J, et al. MNPs@anionic MOFs/ERGO with the size selectivity for the electrochemical determination of H_2O_2 released from living cells. *Biosens. Bioelectron*. 2018;116:81–88. doi:10.1016/j.bios.2018.05.045.
21. Salimi A, Mahdioun M, Noorbakhsh A, Abdolmaleki A, Ghavami R. A novel non-enzymatic hydrogen peroxide sensor based on single walled carbon nanotubes–manganese complex modified glassy carbon electrode. *Electrochim. Acta*. 2011;56:3387–3394. doi:10.1016/j.electacta.2010.12.070.
22. Zhang C, Wang M, Liu L, Yang X, Xu X. Electrochemical investigation of a new Cu-MOF and its electrocatalytic activity towards H_2O_2oxidationinalkalinesolution. *Electrochem. Commun*. 2013;33:131–134. doi:10.1016/j.elecom.2013.04.026.
23. Naseri M, Fotouhi L, Ehsani A. Nanostructured Metal Organic Framework Modified Glassy Carbon Electrode as a High Efficient Non-Enzymatic Amperometric Sensor for Electrochemical Detection of H_2O_2. *J. Electrochem. Sci. Technol*. 2018;9:28–36. doi:10.5229/JECST.2018.9.1.28.
24. Meng W, Xu S, Dai L, Li Y, Zhu J, Wang L. An enhanced sensitivity towards H2O2 reduction based on a novel Cu metal–organic framework and acetylene black modified electrode. *Electrochim. Acta*. 2017;230:324–332. doi:10.1016/j.electacta.2017.02.017.
25. Zhang D, Zhang J, Zhang R, et al. 3D porous metal-organic framework as an efficient electrocatalyst for nonenzymatic sensing application. *Talanta* 2015;144:1176–1181. doi:10.1016/j.talanta.2015.07.091.
26. Cobos M, De-La-Pinta I, Quindós G, Fernández MJ, Fernández MD. Graphene Oxide–Silver Nanoparticle Nanohybrids: Synthesis, Characterization, and Antimicrobial Properties. *Nanomater*. 2020;10:376. doi:10.3390/nano10020376.
27. Arul P, John SA. Silver nanoparticles built-in zinc metal organic framework modified electrode for the selective non-enzymatic determination of H_2O_2. *Electrochim. Acta.* 2017;235:680–689. doi:10.1016/j.electacta.2017.03.097.
28. Zhang D, Zhang J, Shi H, et al. Redox-active microsized metal-organic framework for efficient nonenzymatic H_2O_2 sensing. *Sens. Actuators B Chem*. 2015;221:224–229. doi:10.1016/j.snb.2015.06.079.
29. Lopa NS, Rahman MM, Ahmed F, Chandra S, Ryu T, Kim W. A base-stable metal-organic framework for sensitive and non-enzymatic electrochemical detection of hydrogen peroxide. *Electrochim. Acta*. 2018;274:49–56. doi:10.1016/j.electacta.2018.03.148.
30. Wang MQ, Zhang Y, Bao SJ, Yu YN, Ye C. Ni(II)-Based Metal-Organic Framework Anchored on Carbon Nanotubes for Highly Sensitive Non-Enzymatic Hydrogen Peroxide Sensing. *Electrochim. Acta*. 2016;190:365–370. doi:10.1016/j.electacta.2015.12.199.
31. Dang W, Sun Y, Jiao H, Xu L, Lin M. AuNPs-NH_2/Cu-MOF modified glassy carbon electrode as enzyme-free electrochemical sensor detecting H_2O_2. *J. Electroanal. Chem*. 2020;856:113592. doi:10.1016/j.jelechem.2019.113592.
32. Liu X, Chen W, Lian M, Chen X, Lu Y, Yang W. Enzyme immobilization on ZIF-67/MWCNT composite engenders high sensitivity electrochemical sensing. *J. Electroanal. Chem*. 2019;833:505–511. doi:10.1016/j.jelechem.2018.12.027.
33. Mathew G, Daniel M. Real-time electrochemical quantification of H_2O_2 in living cancer cells using Bismuth based MOF. *J. Electroanal. Chem*. 2022;914:116255. doi:10.1016/j.jelechem.2022.116255.
34. Liu B, Wang X, Zhai Y, et al. Facile preparation of well conductive 2D MOF for nonenzymatic detection of hydrogen peroxide: Relationship between electrocatalysis and metal center. *J. Electroanal. Chem*. 2020;858:113804. doi:10.1016/j.jelechem.2019.113804.
35. Sherino B, Mohamad S, Halim SNA, Manan NA. Electrochemical detection of hydrogen peroxide on a new microporous Ni–metal organic framework material-carbon paste electrode. *Sens. Actuators B: Chem*. 2018;254:1148–1156. doi:10.1016/j.snb.2017.08.002.
36. Yadav DK, Ganesan V, Sonkar PK, Gupta R, Rastogi P. Electrochemical investigation of gold nanoparticles incorporated zinc based metal-organic framework for selective recognition of nitrite and nitrobenzene. *Electrochim. Acta.* 2016;200:276–282. doi:10.1016/j.electacta.2016.03.092.
37. Kung CW, Chang TH, Chou LY, et al. Porphyrin-based metal–organic framework thin films for electrochemical nitrite detection. *Electrochem. Commun*. 2015;58:51–56. doi:10.1016/j.elecom.2015.06.003.
38. Yuan B, Zhang J, Zhang R, et al. Cu-based metal–organic framework as a novel sensing platform for the enhanced electro-oxidation of nitrite. *Sens. Actuators B Chem*. 2016;222:632–637. doi:10.1016/j.snb.2015.08.100.
39. Zhang Y, Bo X, Nsabimana A, Han C, Li M, Guo L. Electrocatalytically active cobalt-based metal–organic framework with incorporated macroporous carbon composite for electrochemical applications. *J. Mater. Chem. A*. 2014;3:732–738. doi:10.1039/C4TA04411H.
40. Li J, Xia J, Zhang F, et al. An electrochemical sensor based on copper-based metal-organic frameworks-graphene composites for determination of dihydroxybenzene isomers in water. *Talanta* 2018;181:80–86. doi:10.1016/j.talanta.2018.01.002.

41. Wang Y, Wang L, Chen H, Hu X, Ma S. Fabrication of Highly Sensitive and Stable Hydroxylamine Electrochemical Sensor Based on Gold Nanoparticles and Metal–Metalloporphyrin Framework Modified Electrode. *ACS Appl. Mater. Interfaces*. 2016;8:18173–18181. doi:10.1021/acsami.6b04819.
42. Zhang J, Xu X, Chen L. An ultrasensitive electrochemical bisphenol A sensor based on hierarchical Ce-metal-organic framework modified with cetyltrimethylammonium bromide. *Sens. Actuators B Chem*. 2018;261:425–433. doi:10.1016/j.snb.2018.01.170.
43. Shi Y, Zhang Y, Wang Y, Huang H, Ma J. Amperometric Sensing of Paracetamol Using a Glassy Carbon Electrode Modified with a Composite of Water–Stable Metal–Organic Framework and Gold Nanoparticles. *Int. J. Electrochem. Sci*. 2018;13:7643–7654. doi:10.20964/2018.08.65.
44. Hadi M, Poorgholi H, Mostaanzadeh H. Determination of metformin at metal-organic framework (Cu-BTC) nanocrystals/multi-walled carbon nanotubes modified glassy carbon electrode : research article. *S. Afr. J. Chem*. 2016;69:132–139. doi:10.10520/EJC190103.
45. Xiao L, Xu R, Yuan Q, Wang F. Highly sensitive electrochemical sensor for chloramphenicol based on MOF derived exfoliated porous carbon. *Talanta* 2017;167:39–43. doi:10.1016/j.talanta.2017.01.078.
46. Cheng Y, Ma B, Tan CP, et al. Hierarchical macro-microporous ZIF-8 nanostructures as efficient nano-lipase carriers for rapid and direct electrochemical detection of nitrogenous diphenyl ether pesticides. *Sens. Actuators B Chem*. 2020;321:128477. doi:10.1016/j.snb.2020.128477.
47. Zhang J, Xu X, Qiang Y. Ultrasensitive electrochemical aptasensor for ochratoxin A detection using AgPt bimetallic nanoparticles decorated iron-porphyrinic metal-organic framework for signal amplification. *Sens. Actuators B Chem*. 2020;312:127964. doi:10.1016/j.snb.2020.127964.
48. Mahmoudi E, Fakhri H, Hajian A, Afkhami A, Bagheri H. High-performance electrochemical enzyme sensor for organophosphate pesticide detection using modified metal-organic framework sensing platforms. *Bioelectrochemistry* 2019;130:107348. doi:10.1016/j.bioelechem.2019.107348.
49. Roushani M, Valipour A, Saedi Z. Electroanalytical sensing of Cd^{2+} based on metal–organic framework modified carbon paste electrode. *Sens. Actuators B Chem*. 2016;233:419–425. doi:10.1016/j.snb.2016.04.106.
50. Yin H, He H, Li T, et al. Ultra-sensitive detection of multiplexed heavy metal ions by MOF-derived carbon film encapsulating BiCu alloy nanoparticles in potable electrochemical sensing system. *Anal. Chim. Acta*. 2023;1239:340730. doi:10.1016/j.aca.2022.340730.
51. Wang Y, Wu Y, Xie J, Hu X. Metal–organic framework modified carbon paste electrode for lead sensor. *Sens. Actuators B Chem*. 2013;177:1161–1166. doi:10.1016/j.snb.2012.12.048.
52. Huo D, Zhang Y, Li N, et al. Three-dimensional graphene/amino-functionalized metal–organic framework for simultaneous electrochemical detection of Cd(II), Pb(II), Cu(II), and Hg(II). *Anal. Bioanal. Chem*. 2022;414:1575–1586. doi:10.1007/s00216-021-03779-6.
53. Wang FF, Liu C, Yang J, Xu HL, Pei WY, Ma J. A Sulfur-Containing Capsule-Based Metal-Organic electrochemical sensor for Super-Sensitive capture and detection of multiple Heavy-Metal ions. *Chem. Eng. J*. 2022;438:135639. doi:10.1016/j.cej.2022.135639.
54. Nguyen MB, Nga D, Vu TT, et al. Novel nanoscale Yb-MOF used as highly efficient electrode for simultaneous detection of heavy metal ions. *J. Mater. Sci*. 2021;56. doi:10.1007/s10853-021-05815-3.
55. Ru J, Wang X, Cui X, et al. GaOOH-modified metal-organic frameworks UiO-66-NH_2: Selective and sensitive sensing four heavy-metal ions in real wastewater by electrochemical method. *Talanta* 2021;234:122679. doi:10.1016/j.talanta.2021.122679.
56. Wang Y, Ge H, Wu Y, Chen H, Hu X. Construction of an electrochemical sensor based on amino-functionalized metal-organic frameworks for differential pulse anodic stripping voltammetric determination of lead. *Talanta* 2014;129:100–105. doi:10.1016/j.talanta.2014.05.014.
57. Chen X, Zhao JX, Wang JW, et al. Doping ZIF-67 with transition metals results in bimetallic centers for electrochemical detection of Hg(II). *Electrochim. Acta*. 2021;387:138539. doi:10.1016/j.electacta.2021.138539.
58. Niu B, Yao B, Zhu M, Ying S, Chen Z. Carbon paste electrode modified with fern leave-like MIL-47(as) for electrochemical simultaneous detection of Pb(II), Cu(II) and Hg(II). *J Electroanal. Chem*. 2021;886:115121. doi:10.1016/j.jelechem.2021.115121.
59. Ye W, Li Y, Wang J, et al. Electrochemical detection of trace heavy metal ions using a Ln-MOF modified glass carbon electrode. *J. Solid State Chem*. 2020;281:121032. doi:10.1016/j.jssc.2019.121032.
60. Quang Khieu D, Thi Thanh M, Vinh Thien T, et al. Synthesis and Voltammetric Determination of Pb(II) Using a ZIF-8-Based Electrode. *J. Chem*. 2018;2018:e5395106. doi:10.1155/2018/5395106.
61. Lu M, Deng Y, Luo Y, et al. Graphene Aerogel–Metal–Organic Framework-Based Electrochemical Method for Simultaneous Detection of Multiple Heavy-Metal Ions. *Anal. Chem*. 2019;91:888–895. doi:10.1021/acs.analchem.8b03764.
62. Pournara A, Margariti A, D. Tarlas G, et al. A Ca^{2+} MOF combining highly efficient sorption and capability for voltammetric determination of heavy metal ions in aqueous media. *J. Mater. Chem. A*. 2019;7:15432–15443. doi:10.1039/C9TA03337H.
63. Ma L, Zhang X, Ikram M, Wu H, Shi K. Controllable synthesis of an intercalated ZIF-67/EG structure for the detection of ultratrace Cd^{2+}, Cu^{2+}, $Hg^{2+}$and Pb^{2+}ions. *Chem. Eng. J*. 2020;395:125216. doi:10.1016/j.cej.2020.125216.
64. Cruz-Navarro JA, Hernandez-Garcia F, Alvarez Romero GA. Novel applications of metal-organic frameworks (MOFs) as redox-active materials for elaboration of carbon-based electrodes with electroanalytical uses. *Coord. Chem. Rev*. 2020;412:213263. doi:10.1016/j.ccr.2020.213263.
65. Yang H, Peng C, Han J, Wang L. Three-dimensional macroporous Carbon/Zr-2,5-dimercaptoterephthalic acid metal-organic frameworks nanocomposites for removal and detection of Hg(II). *Sens. Actuators B Chem*. 2020;320:128447. doi:10.1016/j.snb.2020.128447.
66. Wang C, Niu Q, Liu D, Dong X, You T. Electrochemical sensor based on Bi/Bi_2O_3 doped porous carbon composite derived from Bi-MOFs for Pb^{2+} sensitive detection. *Talanta* 2023;258:124281. doi:10.1016/j.talanta.2023.124281.