

MXene/SWCNT/ABSA for Electrochemical Detection of Chloramphenicol

Chevuru Sai Shreya Reddy¹, Ashok K. Sundramoorthy^{1*}, Dhanraj Ganapathy¹

¹Centre for Nano-Biosensors, Department of Prosthodontics and Materials Science, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai, 600077, Tamil Nadu, India.

*Corresponding author: Ashok K. Sundramoorthy, Centre for Nano-Biosensors, Department of Prosthodontics and Materials Science, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai, 600077, Tamil Nadu, India

Email: ashokkumars.sdc@saveetha.com

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ABSTRACT

Background

Chloramphenicol (CAP) is a broad-spectrum antibiotic widely used to treat bacterial infections; however, its excessive use and persistence in environmental and biological samples necessitate the development of sensitive detection methods. In this study, a MXene/SWCNT/ABSA-modified glassy carbon electrode (GCE) was fabricated and evaluated for the electrochemical detection of chloramphenicol.

Materials and Methods

The composite was prepared by combining Ti₃C₂T_x MXene, single-walled carbon nanotubes (SWCNTs), and 2-aminobenzenesulfonic acid (ABSA), followed by electropolymerisation on the electrode surface. Electrochemical performance was investigated using cyclic voltammetry. FESEM and UV-Vis analyses confirmed the successful fabrication of the nanocomposite.

Results

The modified electrode exhibited a significantly higher capacitive current than the bare GCE, confirming successful surface modification. In the presence of chloramphenicol, the MXene/SWCNT/ABSA-modified GCE demonstrated enhanced electrocatalytic activity with a stronger oxidation response at lower potential. The sensor showed a linear response over increasing chloramphenicol concentrations and maintained stable performance across scan rates ranging from 10 to 250 mV s⁻¹.

Conclusion

These results demonstrate that the MXene/SWCNT/ABSA-modified GCE is a promising platform for the sensitive electrochemical detection of chloramphenicol.

Keywords: Chloramphenicol, electrochemical detection, MXene, SWCNT, ABSA.

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INTRODUCTION

Chloramphenicol (CAP) is a broad-spectrum antibiotic belonging to the class of antimicrobial agents that inhibit bacterial protein synthesis by binding to the 50S ribosomal subunit. Structurally, chloramphenicol is the D-three isomer of a small molecule comprising a p-nitrobenzene ring linked to a dichloroacetyl group through a 2-amino-1,3-propanediol moiety (1). It has been widely used for the treatment of various severe bacterial infections and exhibits bacteriostatic activity against a broad range of microorganisms. However, it acts bactericidally

against specific pathogens such as *Haemophilus influenzae*, *Streptococcus pneumoniae*, and *Neisseria meningitidis*(2). Chloramphenicol can be administered both orally and parenterally and is metabolized primarily in the liver before being excreted through the kidneys(3). Despite its therapeutic efficacy, chloramphenicol is associated with significant adverse effects, including metabolic acidosis, aplastic anemia, thrombocytopenia, hypotension, and, in severe cases, coma. Therefore, sensitive and reliable methods for its detection are of considerable importance(4).

Several analytical techniques have been developed

for the determination of chloramphenicol, including liquid chromatography-tandem mass spectrometry (LC-MS/MS)(5), gas chromatography-mass spectrometry (GC-MS), antibody-based immunoassays(6), and high-performance liquid chromatography (HPLC)(7). Although these methods offer excellent sensitivity and selectivity, their practical application is often limited by complex sample preparation procedures, expensive instrumentation, and time-consuming analytical protocols(8). In recent years, electrochemical sensing(9) has emerged as a promising alternative due to its simplicity, rapid response, cost-effectiveness, and high sensitivity. Various electrochemical platforms based on graphene oxide(10), three-dimensional reduced graphene oxide architectures (11), and palladium nanoparticle-decorated reduced graphene oxide(12) have been reported for chloramphenicol detection.

Single-walled carbon nanotubes (SWCNTs) are cylindrical nanostructures with diameters typically around 1 nm(13) and possess exceptional electrical, thermal, and mechanical properties(14). Their high electrical conductivity, large specific surface area, and excellent electron-transfer capabilities make them attractive materials for applications in electronics, biotechnology, and sensing technologies(15). Furthermore, SWCNTs have demonstrated considerable potential in biomedical and dental applications, including tissue engineering, restorative materials, and biosensing platforms(16).

Among emerging nanomaterials, MXenes have gained significant attention owing to their unique two-dimensional layered structure, excellent conductivity, hydrophilic surface chemistry, and tunable physicochemical properties(17). MXenes can function either as active sensing materials or as supports for other functional nanomaterials(18), making them highly suitable for electrochemical sensing applications(19). Previous studies have successfully employed MXene-based nanocomposites for the electrochemical detection of environmental pollutants, including pesticides, nitrites, and heavy metal ions(20).

4-Aminobenzenesulfonic acid (ABSA), commonly known as sulfanilic acid, is an aromatic organic compound with a molecular weight of 173.19 g mol⁻¹. Due to the presence of both amino and sulfonic acid functional groups, ABSA exhibits amphiphilic characteristics and has been utilized in various chemical and

electrochemical applications. Its functional groups facilitate surface modification, improve material stability, and enhance electron-transfer processes(21). Consequently, ABSA has been widely explored in the fabrication of electrochemical sensing platforms for the detection of a variety of analytes.

In the present study, an MXene/SWCNT/ABSA nanocomposite-modified glassy carbon electrode (GCE) was fabricated and employed for the electrochemical detection of chloramphenicol. The synergistic combination of MXene, SWCNTs, and ABSA is expected to enhance electron transfer, increase the electroactive surface area, and improve the electrocatalytic performance of the sensor toward chloramphenicol detection.

MATERIALS AND METHODS

Preparation of MXene (Ti₃C₂T_x) Dispersion:

MXene (Ti₃C₂T_x) powder was synthesized via a self-propagating high-temperature method under a nitrogen atmosphere. Titanium (Ti), aluminum (Al), and carbon (C) precursor powders were mixed in a mass ratio of 3:1:2 and ball-milled for 12 h at room temperature to ensure homogeneous mixing. The resulting powder mixture was then heated to 1100 °C for 2 h in a tubular furnace under a continuous nitrogen atmosphere, with a heating rate of 5 °C min⁻¹. After cooling to room temperature, the obtained black powder was collected and etched using 40% hydrofluoric acid (HF) under continuous magnetic stirring (1000 rpm) for 24 h to remove the aluminum layers.

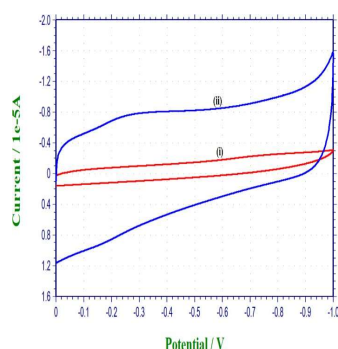
The etched product was subsequently centrifuged and washed repeatedly with distilled water until a neutral pH was achieved. The material was then dried at 70 °C in a hot-air oven to obtain MXene powder. To prepare the MXene dispersion, 10 mg of MXene powder was dispersed in 10 mL of distilled water and sonicated for 10 min at room temperature(22).

Preparation of MXene/SWCNT/ABSA Nanocomposite

A dispersion of single-walled carbon nanotubes (SWCNTs) was prepared by dispersing

1 mg of SWCNTs in 2 mL of distilled water followed by sonication for 10 min at room temperature. Separately, a 0.5 mM solution of 4-aminobenzenesulfonic acid (ABSA) was prepared by dissolving the required amount of ABSA in 10 mL of distilled water. The MXene dispersion, SWCNT dispersion, and ABSA solution were then mixed in a volume ratio of 1:1:1 (0.5 mL each) and sonicated for 5 min at room temperature to obtain a homogeneous MXene/SWCNT/ABSA nanocomposite suspension.

Modification of Glassy Carbon Electrode (GCE)



Prior to modification, the glassy carbon electrode (GCE) was mechanically polished using 0.05 μm alumina slurry on a polishing pad. The electrode was thoroughly rinsed with distilled water and dried using Kimwipes. Subsequently, 10 μL of the MXene/SWCNT/ABSA

nanocomposite suspension was drop-cast onto the surface of the cleaned GCE and dried at 50 $^{\circ}\text{C}$ for 10 min in a hot-air oven. After cooling to room temperature, the modified electrode was gently rinsed with distilled water to remove any loosely attached particles.

Electropolymerisation of the Modified Electrode

Electropolymerisation of ABSA on the modified electrode surface was carried out by cyclic voltammetry (CV) in 0.1 M H_2SO_4 solution. The potential was cycled between -0.5 V and $+1.8$ V for 20 consecutive cycles at a scan rate of 100 mV s^{-1} , resulting in the formation of a polymerized ABSA film on the electrode surface. Following electropolymerisation, CV was recorded in 0.1 M H_2SO_4 within a potential window of 0.0 to $+0.8$ V to confirm polymer formation. The appearance of the characteristic polymerization peak indicated the successful

formation of the poly (ABSA) layer on the MXene/SWCNT-modified GCE. The resulting MXene/SWCNT/poly (ABSA)-modified GCE was subsequently used for all electrochemical measurements(23).

RESULTS

Electrochemical Characterization of the Modified Electrode in PBS

The electrochemical behavior of the bare glassy carbon electrode (GCE) and the MXene/SWCNT/poly (ABSA)-modified GCE was investigated by cyclic voltammetry in 0.1 M phosphate-buffered saline (PBS, pH 7.4). CV measurements were performed within a potential window of 0 to -1.0 V at a scan rate of 50 mV s^{-1} . **Figure 1** presents the CV responses of (i) bare GCE and (ii) MXene/SWCNT/poly (ABSA)-modified GCE in PBS. The modified electrode exhibited a significantly higher capacitive current than the bare electrode, indicating the successful deposition of the MXene/SWCNT/poly (ABSA) nanocomposite on the electrode surface and its enhanced electrochemical activity.

Figure 1. Cyclic voltammograms of (i) bare GCE and (ii) MXene/SWCNT/poly (ABSA)-modified GCE in 0.1 M PBS.

Electrochemical Detection of Chloramphenicol

The electrocatalytic activity of the modified electrode toward chloramphenicol (CAP) was evaluated by recording CVs in 0.1 M PBS containing 50 μM chloramphenicol. As shown in **Figure 2**, the MXene/SWCNT/poly (ABSA)-modified GCE exhibited a significantly enhanced current response compared with the bare GCE. The oxidation peak observed at approximately -0.58 V for the modified electrode was considerably higher than that of the bare electrode, demonstrating improved electrocatalytic activity toward chloramphenicol oxidation. The bare GCE displayed a relatively weak current response at approximately -0.70 V, whereas the modified electrode generated a stronger current signal at a less negative potential (-0.57 V). These results indicate that the MXene/SWCNT/poly (ABSA) nanocomposite facilitates electron transfer and enhances the

electrochemical oxidation of chloramphenicol, making it suitable for sensing applications(24).

concentrations (100–250 μM) using the MXene/SWCNT/poly (ABSA)-modified GCE.

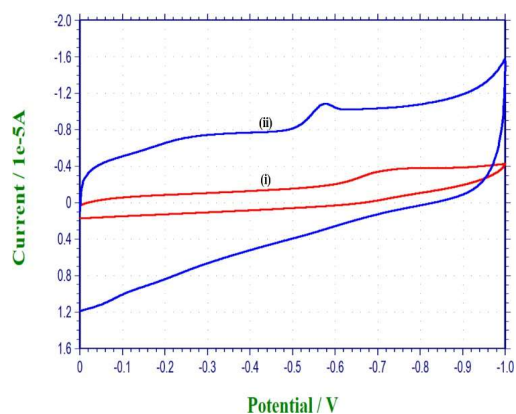


Figure 2. Cyclic voltammograms of (i) bare GCE and (ii) MXene/SWCNT/poly (ABSA)-modified GCE in 0.1 M PBS containing 50 μM chloramphenicol.

Effect of Chloramphenicol Concentration

The sensing performance of the MXene/SWCNT/poly (ABSA)-modified GCE was further investigated at different chloramphenicol concentrations. CV measurements were recorded in 0.1 M PBS containing chloramphenicol concentrations ranging from 100 to 250 μM at a scan rate of 50 mV s^{-1} . As illustrated in **Figure 3**, the oxidation peak current increased progressively with increasing chloramphenicol concentration. A linear relationship between current response and chloramphenicol concentration was observed, indicating the excellent analytical performance of the modified electrode for quantitative detection.

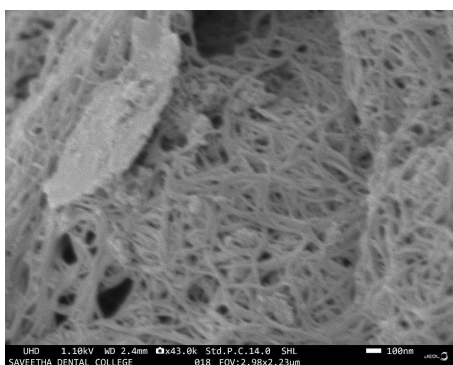


Figure 3. Cyclic voltammograms obtained at different chloramphenicol

Effect of Scan Rate

The influence of scan rate on the electrochemical response of chloramphenicol was evaluated using 350 μM chloramphenicol in 0.1 M PBS. CV measurements were performed at scan rates ranging from 10 to 250 mV s^{-1} . As shown in **Figure 4**, the oxidation current increased continuously with increasing scan rate. The linear increase in current response indicates efficient electron-transfer kinetics and good electrochemical stability of the modified electrode, demonstrating its suitability for sensing applications(25).

Figure 4. Cyclic voltammograms recorded at scan rates ranging from 10 to 250 mV s^{-1} in the presence of 350 μM chloramphenicol.

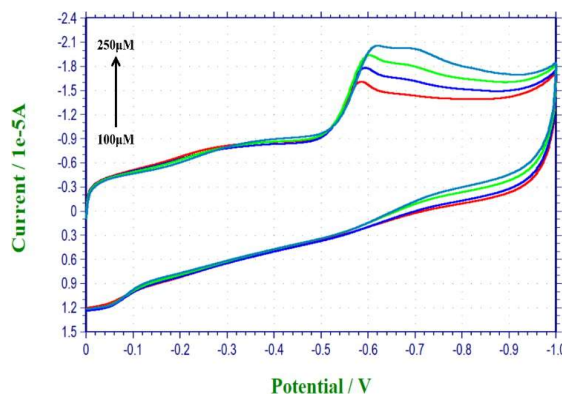
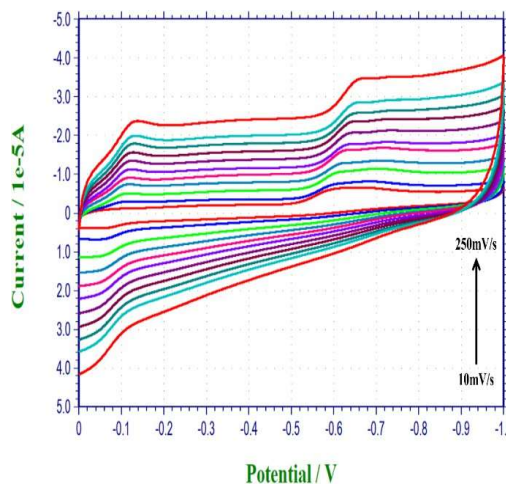


Figure 5. FESEM image of the

MXene/SWCNT/poly(ABSA) nanocomposite.

Characterization Studies: Field Emission Scanning Electron Microscopy (FESEM)

The surface morphology of the MXene/SWCNT/poly (ABSA) nanocomposite was examined using FESEM. The FESEM image in **Figure 5** reveals the characteristic layered MXene structure, decorated with SWCNTs and a polymerized ABSA layer. The uniform distribution of SWCNTs on the MXene surface suggests successful composite formation and the development of a conductive network favorable for electron transport.

UV-Visible Spectroscopy

The successful formation of the MXene/SWCNT/poly (ABSA) nanocomposite was further confirmed by UV-Visible spectroscopy. As shown in **Figure 6**, characteristic absorption peaks were observed at 251 nm and 383 nm, corresponding to MXene and SWCNTs, respectively(18). These absorption features confirm the successful incorporation of both components into the nanocomposite structure(26).

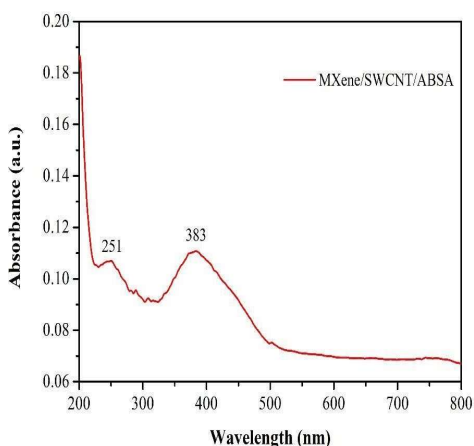


Figure 6. UV-Visible absorption spectrum of the MXene/SWCNT/poly (ABSA) nanocomposite.

DISCUSSION

In the present study, an MXene/SWCNT/poly (ABSA) nanocomposite was successfully fabricated and employed as an electrochemical sensing platform for chloramphenicol detection. The synergistic

combination of MXene, SWCNTs, and poly (ABSA) provided a conductive and electrochemically active surface that significantly enhanced the sensing performance of the glassy carbon electrode. The cyclic voltammetry results demonstrated that the modified electrode exhibited a higher capacitive current than the bare GCE in phosphate-buffered saline, indicating successful surface modification and an increase in the electroactive surface area. The enhanced conductivity can be attributed to the excellent electron-transfer properties of MXene and SWCNTs. In the presence of chloramphenicol, the modified electrode generated a substantially higher oxidation current and a lower oxidation potential compared with the bare electrode. This

behavior suggests improved electrocatalytic activity and faster electron-transfer kinetics, which facilitate the oxidation of chloramphenicol at the electrode surface.

The concentration-dependent studies revealed a linear increase in oxidation current with increasing chloramphenicol concentration, demonstrating the capability of the sensor for quantitative analysis. Similarly, the scan-rate studies showed a proportional increase in current response, indicating stable electrochemical behavior and efficient charge-transfer processes.

FESEM analysis confirmed the successful integration of SWCNTs and poly (ABSA) onto the layered MXene surface, forming a highly conductive interconnected network. Furthermore, UV-Visible spectroscopy verified the successful fabrication of the nanocomposite through the characteristic absorption peaks of MXene and SWCNTs. Overall, the results demonstrate that the MXene/SWCNT/poly (ABSA)-modified GCE possesses excellent electrocatalytic properties and can serve as an efficient sensing platform for chloramphenicol detection.

CONCLUSION

An MXene/SWCNT/poly (ABSA)-modified glassy carbon electrode was successfully fabricated and utilized for the electrochemical detection of chloramphenicol. The modified electrode exhibited enhanced electrochemical activity, improved current response, and favorable electrocatalytic behavior compared with the bare GCE. Characterization studies confirmed the successful formation of the MXene/SWCNT/poly (ABSA) nanocomposite

and its uniform surface morphology. The sensor demonstrated a concentration-dependent linear response toward chloramphenicol and maintained stable electrochemical performance over a wide range of scan rates. These findings highlight the potential of the MXene/SWCNT/poly (ABSA)-modified GCE

as a simple, sensitive, and cost-effective platform for chloramphenicol monitoring in environmental and pharmaceutical applications.

Conflicts of interest

The authors declare that they have no known competing financial interests.

Data availability

All the experimental data obtained in this work are presented in the manuscript itself, and no additional datasets were excluded.

REFERENCES

- Dinos GP, Athanassopoulos CM, Missiri DA, Giannopoulou PC, Vlachogiannis IA, Papadopoulos GE, et al. Chloramphenicol derivatives as antibacterial and anticancer agents: Historic problems and current solutions. *Antibiotics (Basel)*. 2016 June 3;5(2):E20.
- Feder HMJ, Osier C, Maderazo EG. Chloramphenicol: A review of its use in clinical practice. *Clin Infect Dis*. 1981 May 1;3(3):479–91.
- Koup JR, Brodsky B, Lau A, Beam TR Jr. High-performance liquid chromatographic assay of chloramphenicol in serum. *Antimicrob Agents Chemother*. 1978 Sept;14(3):439–43.
- Glazko AJ, Wolf LM. Biochemical studies on chloramphenicol; tissue distribution and excretion studies. *J Pharmacol Exp Ther*. 1949 Aug;96(4 Pt. 1):445–59.
- Tian H. Determination of chloramphenicol, enrofloxacin and 29 pesticides residues in bovine milk by liquid chromatography-tandem mass spectrometry. *Chemosphere*. 2011 Apr;83(3):349–55.
- Impens S, Reybroeck W, Vercammen J, Courtheyn D, Ooghe S, De Wasch K, et al. Screening and confirmation of chloramphenicol in shrimp tissue using ELISA in combination with GC–MS2 and LC–MS2. *Anal Chim Acta*. 2003 Apr;483(1–2):153–63.
- Kim D-M, Rahman MA, Do MH, Ban C, Shim Y-B. An amperometric chloramphenicol immunosensor based on cadmium sulfide nanoparticles modified-dendrimer bonded conducting polymer. *Biosens Bioelectron*. 2010 Mar 15;25(7):1781–8.
- Moudgil P, Bedi JS, Aulakh RS, Gill JPS, Kumar A. Validation of HPLC multi-residue method for determination of fluoroquinolones, tetracycline, sulphonamides and chloramphenicol residues in bovine milk. *Food Anal Methods*. 2019 Feb;12(2):338–46.
- Venkataraman S, Sundramoorthy AK. Waste-derived carbon nanomaterials for electrochemical applications: toward a circular and sustainable future. *RSC Adv*. 2025 Dec 22;16(1):733–47.
- Dong X, Yan X, Li M, Liu H, Li J, Wang L, et al. Ultrasensitive detection of chloramphenicol using electrochemical aptamer sensor: A mini review. *Electrochem Commun*. 2020 Nov;120(106835):106835.
- Sebastian N, Yu W-C, Balram D. Electrochemical detection of an antibiotic drug chloramphenicol based on a graphene oxide/hierarchical zinc oxide nanocomposite. *Inorg Chem Front*. 2019;6(1):82–93.
- Zhang X, Zhang Y-C, Zhang J-W. A highly selective electrochemical sensor for chloramphenicol based on three-dimensional reduced graphene oxide architectures. *Talanta*. 2016 Dec 1;161:567–73.
- Venkataraman S, Atchudan R, Arya S, Mahadevegowda SH, Sundramoorthy AK. Antimicrobial efficacy and mechanistic insights of 0D, 1D, 2D, and 3D nanoparticles: A review. *Mini Rev Med Chem [Internet]*. 2026 Apr 27;26. Available from: <http://dx.doi.org/10.2174/0113895575428691260122055445>
- Yi W, Li Z, Dong C, Li H-W, Li J. Electrochemical detection of chloramphenicol using palladium nanoparticles decorated reduced graphene oxide. *Microchem J*. 2019 July;148:774–83.
- Tomada J, Amsharov K. Single-walled carbon nanotube's end-cap engineering—molecular seeds for controlled synthesis of chirality-pure SWCNT. In: *Reference Module in Chemistry, Molecular Sciences and Chemical Engineering*. Elsevier; 2018.
- Venkataraman A, Amadi EV, Chen Y, Papadopoulos C. Carbon nanotube assembly and integration for applications. *Nanoscale Res Lett*. 2019 July 1;14(1):220.

17. Castro-Rojas MA, Vega-Cantu YI, Cordell GA, Rodriguez-Garcia A. Dental applications of carbon nanotubes. *Molecules*. 2021 July 22;26(15):4423.
18. Venkataraman S, Magesh V, Govindasamy C, Atchudan R, Ganapathy D, Arya S, et al. Mo₂CT_x MXene-based non-enzymatic electrochemical sensor for selective detection of hydrogen peroxide in colorectal cancer cells. *Nanoscale Adv* [Internet]. 2026; Available from: <http://dx.doi.org/10.1039/d6na00025h>
19. Kechagioglou P, Andriotis E, Papagerakis P, Papagerakis S. Multiwalled carbon nanotubes for dental applications. *Methods Mol Biol*. 2019;1922:121–8.
20. Giménez R, Serrano B, San-Miguel V, Cabanelas JC. Recent advances in MXene/epoxy composites: Trends and prospects. *Polymers (Basel)*. 2022 Mar 15;14(6):1170.
21. Damiri F, Rahman MH, Zehravi M, Awaji AA, Nasrullah MZ, Gad HA, et al. MXene (Ti₃C₂T_x)-embedded nanocomposite hydrogels for biomedical applications: A review. *Materials (Basel)*. 2022 Feb 23;15(5):1666.
22. Magesh V, Atchudan R, Arya S, Mahadevegowda SH, Sundramoorthy AK. Tailored synthesis and morphological analysis of Mo₂CT_x and Ti₃C₂□_x MXenes: A study on multilayered and delaminated architectures. *Nanoscale Adv* [Internet]. 2025; Available from: <http://dx.doi.org/10.1039/d5na00669d>
23. Li S, Zhong T, Long Q, Huang C, Chen L, Lu D, et al. A gold nanoparticles-based molecularly imprinted electrochemical sensor for histamine specific-recognition and determination. *Microchem J*. 2021 Dec;171(106844):106844.
24. Martian PC, Tertis M, Anghel CC, Bogosel DF, Trandafir MM, Chirica IM, et al. Advancing chloramphenicol detection through a novel porous organic polymer-enhanced screen-printed electrode. *Talanta*. 2026 Oct 1;308(129873):129873.
25. Elgrishi N, Rountree KJ, McCarthy BD, Rountree ES, Eisenhart TT, Dempsey JL. A practical beginner's guide to cyclic voltammetry. *J Chem Educ*. 2018 Feb 13;95(2):197–206.
26. Magesh V, Govindasamy C, Atchudan R, Ganapathy D, Arya S, Sundramoorthy AK. Synthesis, structural characterization, and electrochemical performance of delaminated mo₂ CT_x MXenes for applications as supercapacitors. *ACS Appl Nano Mater*. 2026 Apr 24;9(16):7126–38.