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RESEARCH ARTICLE

Applications of Eco-Friendly Synthesis of Copper Oxide Nanoparticles in Manufacturing of Sensors for Potentiometric Determination of Tetracycline Hydrochloride

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ABSTRACT

A new type of electrodes was prepared for determination of drugs depended on (TCH- PM-CuO NPs). This work recommended a novel CuO nanoparticles-depended on coated wire sensors for detected tetracycline hydrochloride (TCH) in pure and pharmaceutical formulations. Tetracycline, hydrochloride, and molybdophosphoric acid (PM) were combined in the finding of polymeric poly vinyl chloride (PVC) and o -nitro phenyl octyl ether (o -NPOE) as a solvent mediator to formula an electro-active material is tetracycline- molybdophosphoric acid (TCH-PM). The adapted sensors utilizing TCH-PM-CuO nanoparticles showed high selectivity and sensitivity for the quantification and discrimination of TCH with a linear range 1.0×10^{-9}-1.0×10^{-2} mol L^{-1} and detection limit of 3.0×10^{-10}, 2.5×10^{-10} and 1.5×10^{-10} mol.L^{-1} for TCH-PM-CuO NPs, TCH-PM-CuO NPs with leaves extract of *Myrtus communis* and TCH-PMA-CuO NPs with leaves extract of *Mentha* coated wire electrodes. The proposed electrodes were used for the determination of TCH in pure form, pharmaceutical formulation, respectively.

Keywords: Coated wire electrodes, CuO nanoparticles, Ion-pair, Leaves extract, Tetracycline

Introduction

The technology of nano has achieved huge consideration over time. Nanoparticles are the essential factor of nanotechnology. The particle size of nanoparticles is between 1–100 nanometers which are fabricated of organic matter, metal, metal oxides and carbon. [1] A unique chemical, biological and physical characterizations that the nanoparticles show at nanoscale, due to comparatively greater area of surface vs. the volume, improved steadiness or reactivity in a methods of chemical, increased strength mechanical, etc. [2,3] Nanoparticles are innovative materials in science and technology has a number of applications in fields such as: agriculture, [4,5] medical, electronic, chemical and pharmaceutical. [6–8] From purely metal precursors metal oxide nanoparticles (MONPs) are prepared. These nanoparticles take an important role in various filed of chemistry, material sciences and physics .One of type oxide nanomaterial is CuO metal oxide NPs, which has involved particular consideration because it is the easiest associate of the type of copper composites and displays a variety of suitable physical characterizations for example great conductivity with high temperature, spin dynamics and effects of electron association. [9,10] CuO NPs are ever more benefited in several applications for example in solar energy, gas sensors, catalysis, heat transfer fluids, and batteries. [11] CuO crystal constructions have a narrowband gap, providing beneficial photovoltaic

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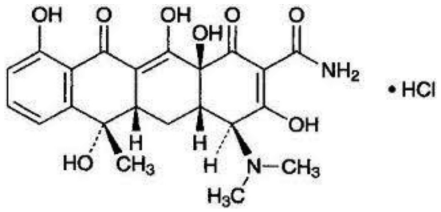

Fig. 1. Schematic representation of chemical structure of tetracycline hydrochloride.

characterizations and photocatalytic.[12] As a result of their easiness of synthesis, nontoxicity scalability, environmental friendliness and low-cost.[13] CuO is a semiconducting composite has a narrow band gap and is applied for photo thermal uses and photoconductive.[14] The field of electro analytical chemistry is potentiometry which is measured the potential below the conditions by no flow of current. The determined potential may possibly then be utilized to detect the analytical quantity, commonly the concentration of several constituent of the analytic solution.

The potential that improves in the cell of electrochemical is the consequence of the free energy variation that would happen if the phenomena of chemical were to advance till the condition of equilibrium has been reached.[15,16] Tetracycline (TCH) antibiotics are a set of broad-spectrum synthetic antibiotics versus a varied range of positive Gram and negative Gram-negative bacteria, thus they are generally utilized in human and veterinary medicine for adjusting diseases and growth of promoting. Tetracyclines are the second main group of antibiotics in terms of manufacture and usage.[17] The structure formulation of TCH as shown in Fig. 1, and it has molecular formulation: $C_{22}H_{24}N_2O_8$.HCl. It is a powder as crystalline (yellow) soluble in water, a little soluble in alcohol, essentially insoluble in ether and acetone.[18] Many methods were applied for the determination of tetracycline hydrochloride such as: Spectrophotometric method[19–21], High performance liquid chromatography HPLC method,[22,23] Electro chemistry method,[24] Chemiluminescence method,[25] and Flow injection method.[26]

In this work, a new modified metal oxide CuO nanoparticle coated wire sensors were prepared to determine TCH in pharmaceutical items with ultrasensitivity and selectivity. The end result displayed that the formed electrodes have some benefits, as well as cost-effectiveness and ease.

Materials and methods

Chemicals

Tetracycline hydrochloride (TCH-HCl), was obtained from (Samara Iraq-SDI) Fluka provided hydrochloric acid 37%,sodium hydroxide, phosphomolybdic acid, cooper sulphate, ethanol 99.9%, methanol 99.9%, acetone 99.9%, tetrahydrofuran (THF) 97.0%, ortho nitro phenyl octyl ether (o-NPOE), and high molecular weight(PVC). The medication form of TCH-HCl, capsules (250 mg).

Equipment

All experimental studies were done by utilizing a double beam UV-visible spectrophotometer model (UV-1650 PC) Shimadzu, Japan, Infrared spectrophotometer SHIMADZU, FTIR-8000 (Japan), Xrd Phillips Xpert PA analytical, Holland. Field Emission Scanning Electron Microscopy (FE-SEM) French MIRA3 with Atomic forces microscope (AFM), AA2000, Angstrom. HANNA instruments pH 2110UK, Romania and reference electrode: Saturated calomel electrode (RE-2BH).

Synthesis of CuO NPs

The precipitation method was applied for synthesizing CuO nanoparticles via preparing 0.1 M of copper sulphate $CuSO_4$ in 100 mL of deionized water to form 0.1 mol.L^{-1}concentration. Solution of sodium hydroxide (0.1 mol L^{-1}) was prepared and little by little added drop wise with continuous stirring till the pH reached 14. The made precipitate was frequently washed three times via deionized water and absolute ethanol. Then, the precipitate was dried up at 80°C for 12 hrs, also it was calcined for 4 hrs at 500°C[27] as shown in Fig. 2.

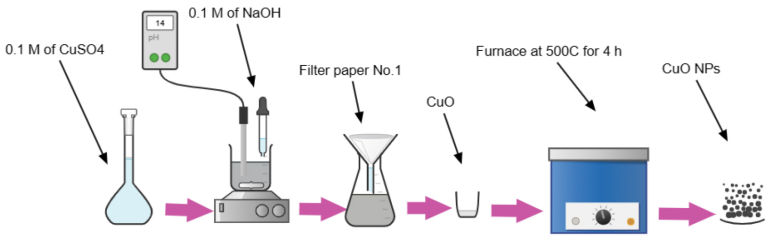

Fig. 2. Synthesis steps of CuONPs.

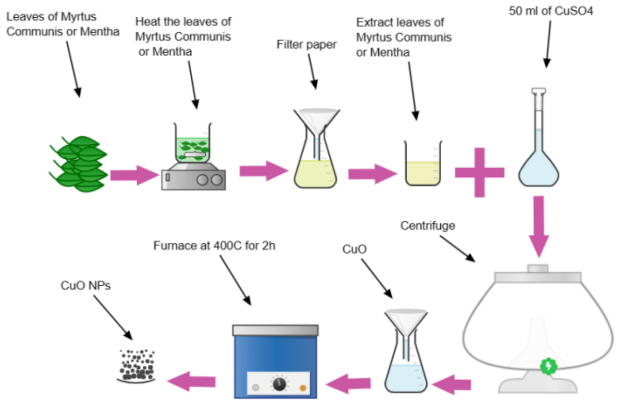

Fig. 3. Green Synthesis of CuO NPs.

Green synthesis of CuO NPs by using extract of myrtus communis and mentha

To synthesis of CuO NPs 1 M copper sulphate was prepared at temperature of room utilizing magnetic stirrer (250 rpm). Next, 30 ml of *Myrtus communis* or *Mentha* leaves extract was added to solution of copper sulphate drop wise, with constant stirring. Future, the solution was saved on magnetic stirrer (250 rpm) for 24 hrs at 60°C for the construction of gel that was dried in oven at 60°C. The green precipitate as a result was calcined in the furnace at 400°C for 6h constructing black CuO nanoparticles.[28] The procedure is shown in Fig. 3.

Study of characterization for nanoparticles

By various spectroscopic and microscopic techniques, the synthesized metal oxide nanoparticles were exposed for checking their nanoscale structures. The optical properties of CuONPs were measured at range of 200 to 800 nm utilizing UV-Vis spectrophotometer. Also FTIR at range 400–4000 $cm^{-1}$to validate the groups of functional of the synthesized CuO NPs. The size of nanoparticles evaluation by calculated peaks of XRD and SEM, and AFM for the study of the morphology of CuO NPs.

Preparation of standard solution

A standard solution of TCH solution was prepared at concentration of 1.0×10^{-2} mol. L^{-1} in 100 ml of distilled water, and then prepared a series of solutions by dilution the stock solution which has a concentration 1.0×10^{-2} mol. L^{-1} via utilizing distilled water.

Construction of ion-pair complex

Ion pair was prepared by combination 100 mL of 1.0×10^{-2} mol.L^{-1} TCH solution with 1.0×10^{-2} mol L^{-1} of PM solution (TCH-PM) was formed as a brown precipitate. The brown precipitate produced was dried at temperature of room for overnight following being filtered and washed.

Sensors design

Cu wire was used for produce the TCH-PM-CuONPs sensors, which had been cleaned with acetone was immersed in mixture of the membrane several times. A membrane mixture containing: CuONPs (5 gm), PVC (1.90 gm), TCH-PM ion pair (1.0 gm), and *o*-NPOE plasticizer (0.35 mL) in 5 mL of THF were constructed the novel sensors. By swirling constantly for 15 min the homogeneous distributed membrane mixture at temperature of room. A thin layer on the surface of the sensors was formed from membrane mixture. After drying, sensors were repetitively immersed in the solution of coated membrane to construct a thickly coated wire membrane.

Calibration graphs

The calibration curves of all sensors showed the potential reading as a function of concentration for a 25 mL of 1.0×10^{-10}–1.0×10^{-2} mol. L^{-1} of TCH standard solutions.

Optimization of TCH-PM-CuONPs sensors

To study the effect of pH for TCH solution at concentration 1.0×10^{-3} mol. L^{-1} on the potential readings of the suggested sensors, the pH was measured for 50 mL of 0.1 mol $L^{-1}$of TCH and HCl or a few drops of 0.1 mol. L^{-1} NaOH were utilized to change the pH. The pH readings as a function of potential measurements of each one sample were shown on pH curves. The assessing the selectivity of the constructed sensor was by separate solution method.

Results and discussion

By UV-VIS spectrophotometry, the copper oxide nanoparticles were measured and the optical absorption properties of the CuO nanoparticles were investigated at room temperature.[29] Fig. 4 shows the UV-Vis absorption spectrum of copper oxide nanoparticles. The spectrum showed the absorbance peak at 369, 327 and 309 nm for CuONPs, CuONPs with leaves extract of *Myrtus communis* and CuONPs with leaves extract of *Mentha*, respectively, corresponding to the characteristic band of copper oxide nanoparticles.[30]

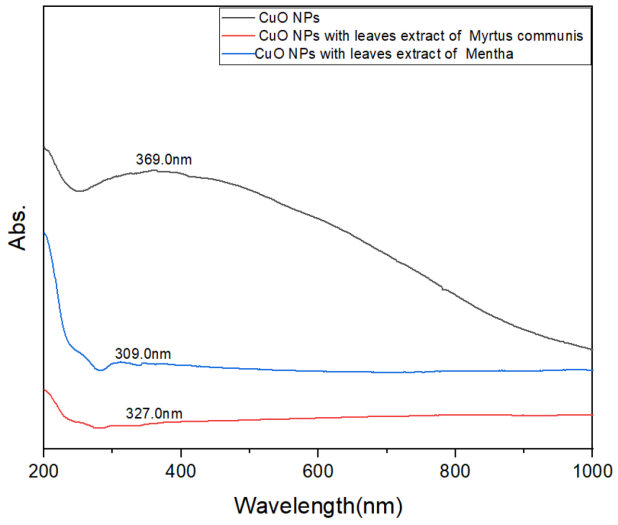

Fig. 4. UV-Visible spectrum of copper oxide nano particles.

The Fourier transform infrared (FTIR) method was used for the identification of functional groups of many organic chemicals, adhesives, paints, coatings, semiconductor, lubricants, coolants, biological samples, materials, inorganics, polymers, minerals and characterization nanoparticles form. In all copper oxide nanoparticles prepared method the stretching band (3322.89-3280.66) cm^{-1} and bending bands (1636.74-1635.33 cm^{-1}) appear to hydroxy group, the other bands to chemical prepared of Cu-O (592.83cm^{-1}), and (589.09-550.35cm^{-1}) with (580.47-561.02cm^{-1}), receptivity for Cu-O prepared by green synthesis with using leaves extract of *Myrtus communis* and *Mentha*. That indicated that the copper oxide nanoparticles were being formed in one phase (CuO) as shown in Fig. 5.

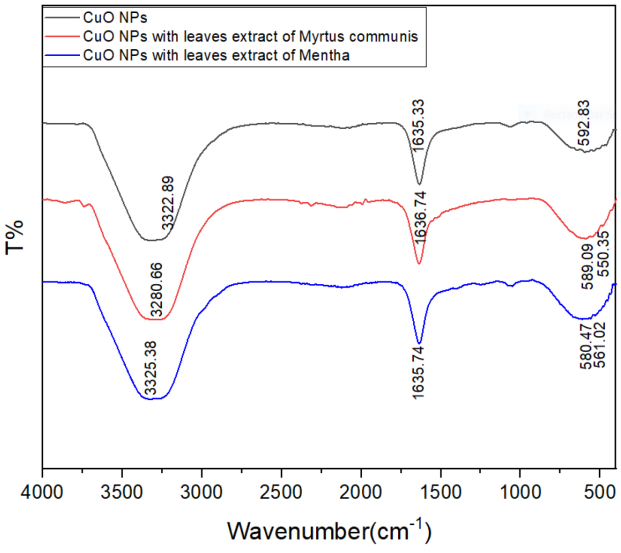

Fig. 5. FTIR spectrum of CuO nanoparticles.

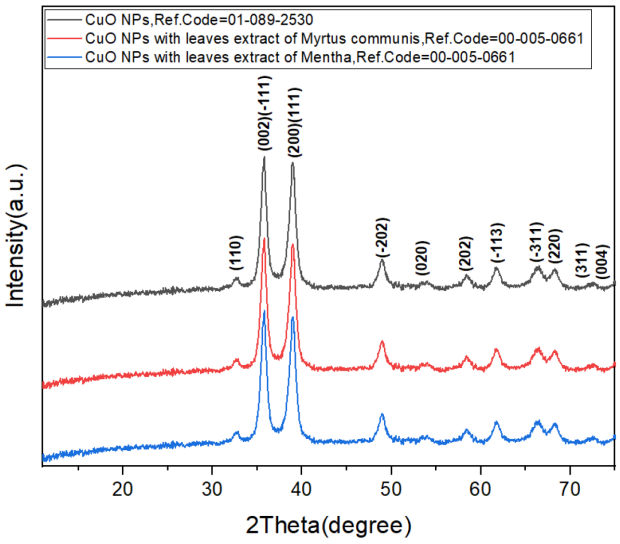

Fig. 6. XRD pattern of CuO particles.

Analysis the x-ray of copper oxide nanoparticles which showed in Fig. 6. The crystal structure and size of the crystallite of the nanoparticles were detected via X-ray diffraction. The diffraction peaks observed over 2θ of 32.62°, 35.77°,38.97°, 48.92°, 53.32°, 58.37°, 61.77°, 66.40°, 68.37°, 72.56°, and 75.04° for CuO nanoparticles and 32.63°, 35.73°,38.97°, 48.91°, 53.41°, 58.33°, 61.73°, 66.51°, 68.45°, 72.31°, and 75.72° for CuO nanoparticles with leaves extract of *Myrtus communis* with 32.92°, 35.87°,38.82°, 48.97°, 53.28°, 58.57°, 61.70°, 66.34°, 68.27°, 72.25° and 75.33°for CuO nanoparticles with leaves extract of *Mentha*, respectively, matched with Miller indices (110), (002)(–111),(200) (111), (-202), (020) (202),(–113), (–311), (220), (311), (004) respectively.

The observed peaks checking the monoclinic structure of CuO-NPs, which match JCPDS map No.01-089-2530 for CuO NPs and 00-005-0661 CuO NPs with leaves extract of *Myrtus communis* and *Mentha*. In addition, no impurity peaks were observed in the diffraction of the green synthesized CuO-NPs, showing the phase purity. Also, the diffraction peaks CuO-NPs were sharp and well defined with high intensities, which indicates the good crystallinity. The average size of the chemical CuO-NP and green synthesized CuO-NP grains was found to be 9.73, 8.76 and 8.58nm for CuO NPs, CuO NPs with leaves extract of *Myrtus communis* and CuO NPs with leaves extract of *Mentha*, respectively.

The surface morphology of the synthesized CuO nanoparticles was investigated using SEM analysis. The SEM images of the CuO NPs are shown in Fig. 7. As may be seen, the mean particle size of CuO is about 32.94, 67.47 and 96.86 nm for CuO NPs,

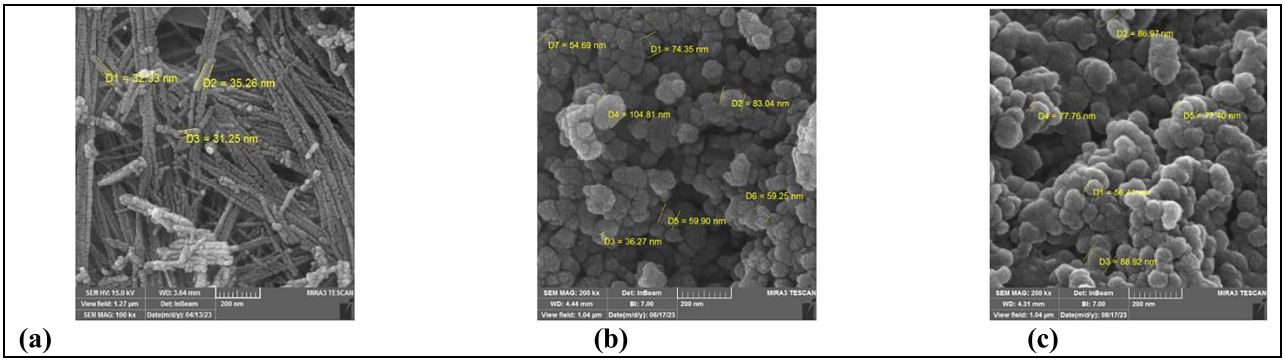

Fig. 7. SEM images of Copper oxide NPs:(a) CuO NPs, (b) CuO NPs with leaves extract of *Myrtus communis* and (c) CuO NPs with leaves extract of *Mentha*.

CuO NPs with leaves extract of *Myrtus communis* and CuO NPs with leaves extract of *Mentha*, respectively, which matched with the results from atomic force microscopy equal to 39.94, 68.77 and 91.75nm for CuO NPs, CuO NPs with leaves extract of *Myrtus communis* and CuO NPs with leaves extract of *Mentha*, respectively as shown in Fig. 8.

Characterization of prepared electrodes

Calibration graph slope for TCH-PM-CuO NPs electrodes were 52.27 and 52.62 and 53.15 mV per decade of the tetracycline concentration and a linear response towards the tetracycline concentration were from 1.0×10^{-9} to 1.0×10^{-2} mol.L^{-1}. Limits of detection were 3.0×10^{-10}, 2.5×10^{-10} and1.5×10^{-10} mol.L^{-1} for TCH-PM-CuO NPs coated wire electrode, TCH-PM-CuO NPs with leaves extract of *Myrtus communis* coated wire electrode and TCH-PM-CuO NPs with leaves extract of *Mentha* coated wire electrode, respectively. The results of TCH-PM-CuO NPs electrodes displayed in Table 1 and Fig. 9.

PH effect on the electrodes responses

The influence of pH on the response of TCH-MP-CuO NPs was studied at 1.0×10^{-3} mol. L^{-1} tetracycline solution. The pH of the solution was various via addition of small volumes of 0.1 mol. L^{-1} solution of both HCl or NaOH and the data are shown in Fig. 10. The profile of potential pH showed that the responses of TCH-MP-CuO NPs electrodes were fairly steady over the pH range 3.5–6.5, 3.0–7.5 and 3.0–8.0 for TCH-MP-CuO NPs coated wire electrode, TCH-MP-CuO NPs with leaves extract of *Myrtus communis* coated wire electrode and TCH-MP-CuO NPs with leaves extract of *Mentha* coated wire electrode.

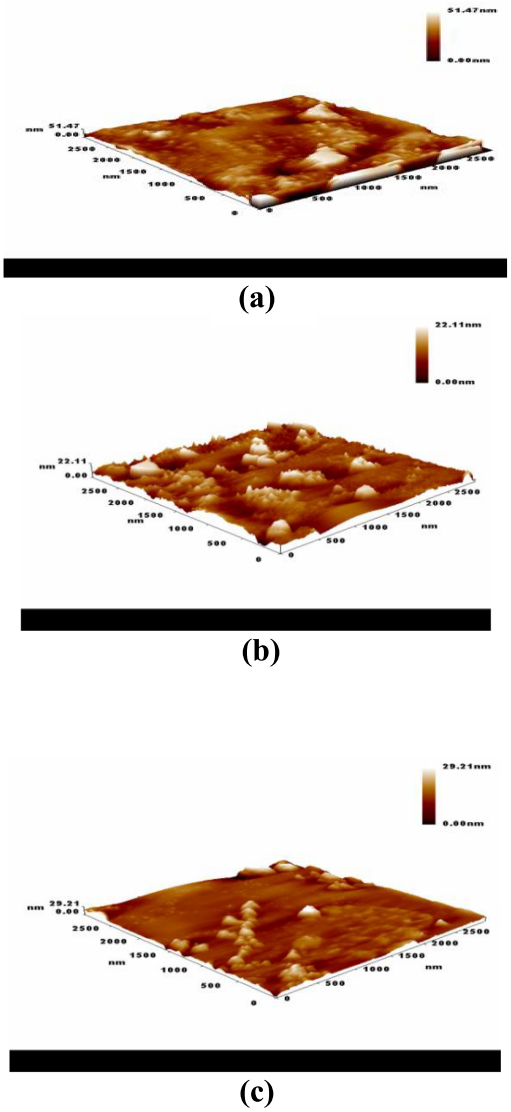

Fig. 8. AFM images of Copper oxide NPs:(a) CuO NPs and (b) for CuO NPs with leaves extract of *Myrtus communis* and (c) for CuO NPs with leaves extract of *Mentha*.

Table 1. Response of TCH-PM-CuO NPs electrodes for tetracycline hydrochloride solution.

Parameters	TCH-PM-CuO NPs coated wire electrode	TCH-PM-CuO NPs with leaves extract of *Myrtus communis* coated wire electrode	TCH-PM-CuO NPs with leaves extract of *Mentha* coated wire electrode
Slope (mV/decade)	52.27	52.62	53.15
Range of Concentration (mol.L^{-1})	1.0×10^{-9}–1.0×10^{-2}	1.0×10^{-9}–1.0×10^{-2}	1.0×10^{-9}–1.0×10^{-2}
LOD(M)	3.0×10^{-10}	2.5×10^{-10}	1.5×10^{-10}
Regre. Eq.Y = mX + b	Y = –22.699ln(x) + 644.27	Y = 22.852ln(x) + 541.8	Y = 23.081ln(x) + 614.2
Range of pH	3.5–6.5	3.0–7.5	3.0–8.0
Correlation coefficient (R^2)	0.9995	0.9990	0.9997
Life of time (day)	52	57	66

*n = 5.

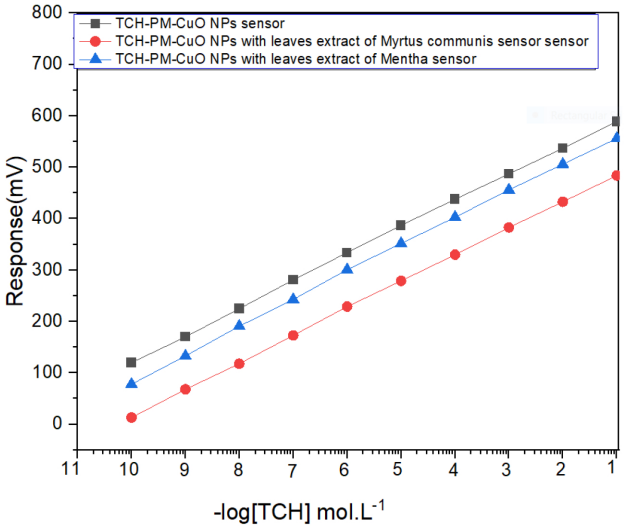

Fig. 9. Calibration curves of TCH-PM-CuO NPs coated wire electrode, TCH-PM-CuO NPs with leaves extract of *Myrtus communis* coated wire electrode and TCH-MP-CuO NPs with leaves extract of *Mentha* coated wire electrode.

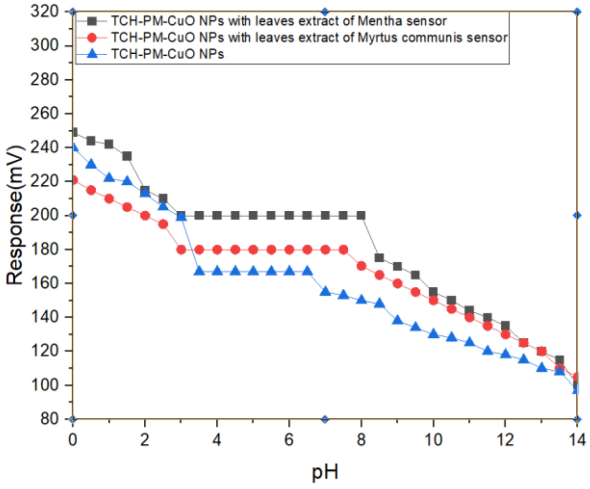

Fig. 10. PH values of TCH-MP-CuO NPs coated wire electrode, TCH-MP-CuO NPs with leaves extract of *Myrtus communis* coated wire electrode and TCH-MP-CuO NPs with leaves extract of *Mentha* coated wire Electrode.

Selectivity of TCH-MP-CuO NPs electrodes

Selectivity, which describes coated wire electrodes specificity toward the target ion in the finding of interfering ions, is the utmost essential characteristic of sensors. The coefficients of selectivity of the tetracycline sensors were assessed via the separate potential method (MPM).[31] The values of selectivity coefficients are shown in Table 2.

Analytical applications

Potentiometric methods applied for estimation the concentration of tetracycline hydrochloride by using TCH-PM-CuO NPs coated wire electrode, TCH-PM-CuO NPs with leaves extract of *Myrtus communis* coated wire electrode and TCH-PM-CuO NPs with leaves extract of *Mentha* coated wire electrode. Linearity, limit of detection, recovery, relative standard deviation were the parameters used for the method validation. The results shown in Table 3. Figs. 11 to 13 show the multi standard addition method for TCH-PM-CuO NPs coated wire electrode, TCH-PM-CuO NPs with leaves extract of *Myrtus communis* coated wire electrode and TCH-PM-CuO NPs with leaves extract of *Mentha* coated wire electrode at concentration 1.0×10^{-3} mol.L^{-1}.

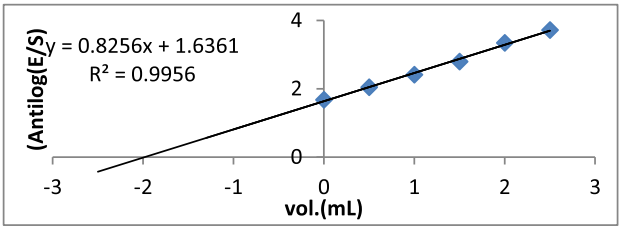

Fig. 11. Antilog (E/S) of TCH-PM-CuO NPs coated wire electrode for 1.0×10^{-3} of Tetracycline hydrochloride.

Table 2. Selectivity coefficient values for TCH-PM-CuO NPs coated wire electrode.

Ion interference	TCH-PM-CuO NPs coated wire electrode	TCH-PM-CuO NPs with leaves extract of *Myrtus communis* coated wire electrode	TCH-PM-CuO NPs with leaves extract of *Mentha* coated wire electrode
K^{+1}	2.1025×10^{-1}	1.9813×10^{-1}	2.2170×10^{-1}
Na^{+1}	2.2920×10^{-1}	2.2592×10^{-1}	1.7866×10^{-1}
CO_3^{-1}	1.2502×10^{-1}	1.7376×10^{-1}	1.5246×10^{-1}
NO_3^{-1}	1.4237×10^{-1}	1.3961×10^{-1}	1.0957×10^{-1}
Mg^{+2}	2.6109×10^{-2}	1.7376×10^{-2}	3.2420×10^{-5}
Zn^{+2}	3.3385×10^{-2}	1.1218×10^{-2}	3.9771×10^{-5}
Al^{+3}	5.4341×10^{-7}	4.5471×10^{-7}	3.1687×10^{-6}
Fe^{+3}	6.1884×10^{-7}	4.9629×10^{-7}	2.2018×10^{-5}
Glucose	1.1857×10^{-8}	2.6147×10^{-6}	1.9560×10^{-9}
Starch	9.5454×10^{-7}	2.4486×10^{-6}	2.0217×10^{-9}

Table 3. Statistical results for TCH-PM-CuO NPs coated wire electrode, TCH-PM-CuO NPs with leaves extract of *Myrtus communis* coated wire electrode and TCH-PM-CuO NPs with leaves extract of *Mentha* coated wire electrode.

		Response by potentiometric method			
Type of Electrodes	Sample	Direct	SAM	SAMS	Titration
TCH-PM- CuO NPs coated wire Electrode	1×10^{-3}	0.9766×10^{-3}	0.9829×10^{-3}	0.9790×10^{-3}	0.9629×10^{-3}
	RSD %	1.5	0.81	-	-
	Rec %	97.66	98.29	97.9	96.29
	RE%	–2.34	–1.71	–2.1	–3.71
TCH-PM-CuO NPs with leaves extract of *Myrtus communis* coated wire Electrode	1×10^{-3}	09966×10^{-3}	0.9841×10^{-3}	09823×10^{-3}	0.9893×10^{-3}
	RSD %	1.2	0.59	-	-
	Rec %	99.66	98.41	98.23	98.93
	RE%	–0.34	–1.59	–1.77	–1.07
TCH-PM-CuO NPs with leaves extract of *Mentha* coated wire Electrode	1×10^{-3}	0.9966×10^{-3}	0.9874×10^{-3}	0.9855×10^{-3}	0.9928×10^{-3}
	RSD %	0.7	0.13	-	-
	Rec %	99.66	98.74	98.55	99.28
	RE%	–0.34	–1.26	–1.45	–0.72

*n = 5.

Table 4. Results of direct method of TCH-PM-CuO NPs, TCH-PM-CuO NPs with leaves extract of *Myrtus communis* and TCH-PM-CuO NPs with leaves extract of *Mentha* coated wire electrodes for determination of tetracycline hydrochloride (TCH).

Type of coated wire electrodes	Conc. of TCH (Capsules) Prepared	Conc. of TCH (Capsules) Founded	RSD%	Re%
TCH-PM-CuO NPs	1×10^{-4}	0.9750×10^{-4}	0.16	97.5
TCH-PM-CuO NPs with leaves extract of *Myrtus communis*	1×10^{-4}	0.9775×10^{-4}	0.71	97.75
TCH-PM-CuO NPs with leaves extract of *Mentha*	1×10^{-4}	0.9950×10^{-4}	0.64	99.5

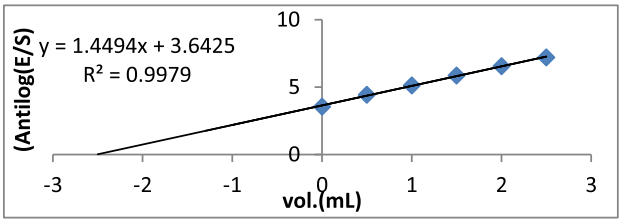

Fig. 12. Antilog (E/S) of TCH-PM- CuO NPs with leaves extract of *Myrtus communis* coated wire electrode 1.0×10^{-3} of Tetracycline hydrochloride

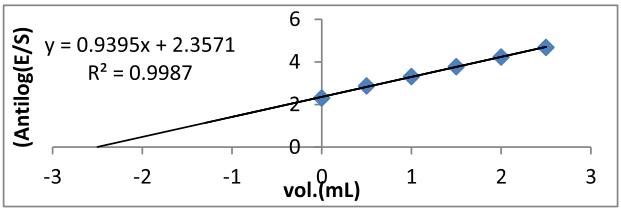

Fig. 13. Antilog (E/S) of TCH-PM- CuO NPs with leaves extract of *Mentha* coated wire electrode for 1.0×10^{-3} of Tetracycline hydrochloride.

Potentiometric determination of TCH in pharmaceutical formulation

The suggested sensors were successfully working for the selective determination of TCH in pharmaceutical product (Tetracycline-250 mg capsules). The determination of TCH was carried out with minimal treatment and without interference utilizing TCH-PM-CuO NPs coated wire electrode, TCH-PM-CuO NPs with leaves extract of *Myrtus communis* coated

wire electrode and TCH-PM-CuO NPs with leaves extract of *Mentha* coated wire electrode as shown in Table 4.

Conclusion

Novel kinds of potentiometric coated wire electrodes were fabricated for evaluation of tetracycline hydrochloride. The sensors gave advanced performances a lower detection limit of 3.0×10^{-10}, 2.5×10^{-10} and 1.5×10^{-10} mol.L^{-1} for TCH-PM-CuO NPs, TCH-PM-CuO NPs with leaves extract of *Myrtus communis* and TCH-PM-CuO NPs with leaves extract of *Mentha* coated wire electrodes, respectively, with potential responses across the range of 1.0×10^{-9}-1.0×10^{-2} for TCH-PM-CuO NPs, TCH-PM-CuO NPs with leaves extract of *Myrtus communis* and TCH-PM-CuO NPs with leaves extract of *Mentha* coated wire electrodes, respectively. In general, the coated wire electrodes suggested here offered high simplicity in design and a very low detection limit in addition to being simple, rapid and inexpensive and could contest with the several sophisticated methods now available.

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Author's declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for republication, which is attached to the manuscript.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee at Al-Nahrain University.

Authors' contribution statement

F. M. A. proposed the topic of research and guidance, and the review and proofreading the research. A. M. A. prepared the samples and analyzed parameters and writing.

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تطبيقات التوليف الصديق للبيئة لجسيمات أوكسيد النحاس النانوية في تصنيع متحسسات للتقدير الجهدي لهيدروكلوريد التتراسايكلين.

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الخلاصة

تم تحضير نوع جديد من الأقطاب الكهربائية لتقدير الادوية والمعتمد على (TCH- PM-CuO NPs). أوصى هذا العمل بجسيمات اوكسيد النحاس النانوية CuO NPs جديدة تعتمد على متحسسات غشاء الأسلاك المطلية لهيدروكلوريد التتراسيكلين المقاس (TCH) في شكله النقي و المستحضرات الصيدلانية. تم المزج بين هيدروكلوريد التتراسيكلين وحمض الموليبدوفوسفوريك (PM) بوجود بولي فينيل كلوريد البوليمري (PVC) و اورثو -نيترو فينيل أوكتيل إيثر (o-NPOE) كوسيط مذيب. وكذلك وجود مادة نشطة كهربائيا هي التتراسيكلين – حمض الموليبدوفوسفوريك (TCH-PM). أظهرت المتحسسات المحضرة بأستخدام الجسيمات النانوية TCH-PM- CuO انتقائية وحساسية عالية للقياس الكمي والتمييز ل TCH بمدى خطي 1.0×10^{-2}-1.0×10^{-9} مول. لتر$^{-1}$ وبحد تحسس 3.0×10^{-10} و2.5×10^{-10} و1.5×10^{-10} مول. لتر$^{-1}$لأأقطاب الاسلاك المطلية المحضرة بأستخدام TCH-PM-CuO NPs, TCH-PM-CuO NPs مع مستخلص أوراق الآس وTCH-PMA-CuO NPs مع مستخلص أوراق النعناع على التوالي, وقد تم استخدام الأقطاب الكهربائية المقترحة لتقدير التتراسايكلينTCH في شكله النقي وفي العقاقير التجارية.

الكلمات المفتاحية: اقطاب الاسلاك المطلية، اوكسيد النحاس النانوي، مزدوج أيوني، مستخلص لااوراق، التتراسايكلين