SIMULTANEOUS/SELECTIVE VOLATMMETRIC DETECTION OF DICLOFENAC AND TETRACYCLINE IN WATER ON GRAPHENE MODIFIED-BORON-DOPED DIAMOND ELECTRODE

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Abstract
The graphene oxide modified boron-doped diamond electrode (GO/BDD) was obtained electrochemically and tested by cyclic voltammetry (CV) to detect diclofenac (DCF) from anti-inflammatory pharmaceuticals class and tetracycline (TC) from antibiotics one, which belongs to emerging pollutants from water. Graphene reduced electrochemically from its oxide showed enhanced sensitivity in determining individual and selective or simultaneous of DCF and TC. The cyclic voltammetry method - based protocol for selective/simultaneous detection of DCF and TC was developed in this study using a commercial boron-doped diamond (BDD) electrode modified with graphene oxide (GO).

1. Introduction
Emerging pollutants (EPs) also known as emerging organic contaminants are defined as synthetic and natural substances, which belong to the category of a wide range of chemicals, personal care products and fire retardant compounds, surfactants, plasticizers, industrial additives, as well as pharmaceuticals, that are not commonly monitored in the environment but have the potential to enter the environment and cause known or suspected adverse ecological and/or human health effects [1-2]. According to studies reported in the literature among the most common pharmaceutical groups detected in water, inflammatory / analgesics (paracetamol, acetylsalicylic acid, ibuprofen and diclofenac) and antibiotics (tetracyclines, macrolides, penicillins) are included [3]. Based on the structures of phenylbutazone, indomethacin and mefenamic acid, diclofenac, a derivative of phenylacetic acid, is the most widely used nonsteroidal anti-inflammatory drug (NSAID) in first-line therapy for pain, acute and chronic inflammation, arthritis, musculoskeletal, dermatomyositis, osteoarthritis, dental pain and other connective tissue systemic diseases [4, 5]. In order to obtain more information on the effects and occurrence of DCF on the environment, the European Union has decided to include temporary DCF in the First Watch List of the Water Framework Directive (EU 2015/495, European Commission) [6]. Whith a broad spectrum of activity against many gram-positive and gram-negative bacteria produced by the Streptomyces genus of Actinobacteria, tetracycline is one of the many types of antibiotics drugs used to treat many different bacterial

infections of the skin, intestines, respiratory tract, and other body systems, used for the treatment of bacterial infections such as syphilis, pneumonia, tuberculosis and plague among others [7-9]. In recent years, due to obtaining high sensitivities and selectivity in the detection of emerging pollutants by applying the electrochemical method and selecting the suitable electrode material, the development of electrochemical detection is of particular interest. As reported in the literature, electrochemical analysis brings considerable advantages compared to classical analytical techniques (HPLC, GC-MS) such as simplicity, shorter analysis time and reduced costs, offering improved performance in terms of reproducibility, sensitivity and detection limit compared to HPLC [10]. Through the proper use of electrode material, electroanalytical methods continue to be updated over time as required, developing higly sensitive detection protocols that are reproducible, reliable, cost-effective, and, with a high level of accuracy and precision. [11]. An electrode recognized for its remarkable properties with very good results in electrochemical detection applications is the commercial diamond electrode doped with boron. However, for better improvement of its electrocatalytic effect and the electroactive surface, graphene oxide is been reported to be suitable for modifying the electrode surface to get the desired performance (reproducibility, low background current, potentially large window and stability) [12–15]. Taking into account the results reported in the literature regarding the detection of DCF and TC on various electrodes, in this study, the modified electrode (GR/BDD) obtained by electrochemical reduction with graphene oxide was tested to detect individually and simultaneously/selectively DCF and TC from aqueous solutions.

2. Experimental
An Autolab potentiostat /galvanostat PGSTAT 302 (Eco Chemie, Utrecht, The Netherlands) was used for performing the electrochemical experiments using with a classical three electrode cell. A platinum counter-electrode, a saturated calomel reference electrode (SCE) and the working boron-doped diamond (BDD) commercial electrode modified with graphene oxide (GO). The BDD commercial electrode provided by Metrohm (Herisau, Switzerland). Electrochemical deposition process with graphene oxide (GO) on the BDD electrode surface occurred at the potential of -1.50 V for 120 s by chronoamperometry (CA) technique, using a suspension of 4 mg/ml GO dispersed in water, when so-called GR/BDD electrode was obtained. The target analyte, diclofenac (DCF), was purchased from Merck and tetracycline (TC), was provided by Antibiotics (Romania). 0.1 M Na_2SO_4 was used as a supporting electrolyte in the electrodetection experiments. The electrochemical methods used in this research study were chronoamperometry (CA) and cyclic voltammetry (CV).

3. Results and discussion
3.1. Cyclic voltammetry (CV)
3.1.1. Individual detection of diclofenac (DCF) by CV
The commercial BDD electrode modified with graphene oxide (GO) reduced electrochemically named GR /BDD electrode was tested by cyclic voltammetry (CV) in the presence of various DCF concentrations and the series of cyclic voltamograms are presented in the Fig. 1. It can be noticed that the oxidation process started very early in comparison with unmodified BDD electrode (the results are not shnown here) at about -0.110 V / SCE, and two oxidation steps were identified, the second started at +0.540 V/SCE. Also, during reverse branch, two cathodic peaks occurred, the first at the potential of +0.150 V and the second at the potential of -0.140V suggesting quasi-reversible oxidation processes. A good linearity anodic and cathodic current vs. diclofenac concentrations was obtained for both regions with correlation coefficient of 0.993 and 0.998 (the obtained sensitivities were 0.021, 0.013, 0.014 and 0.025 $\mu A \cdot \mu M^{-1}$, respectively).
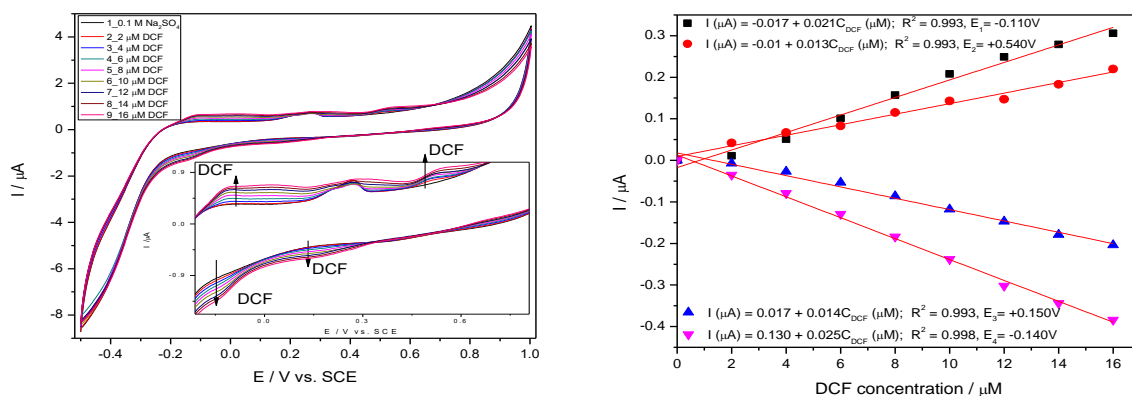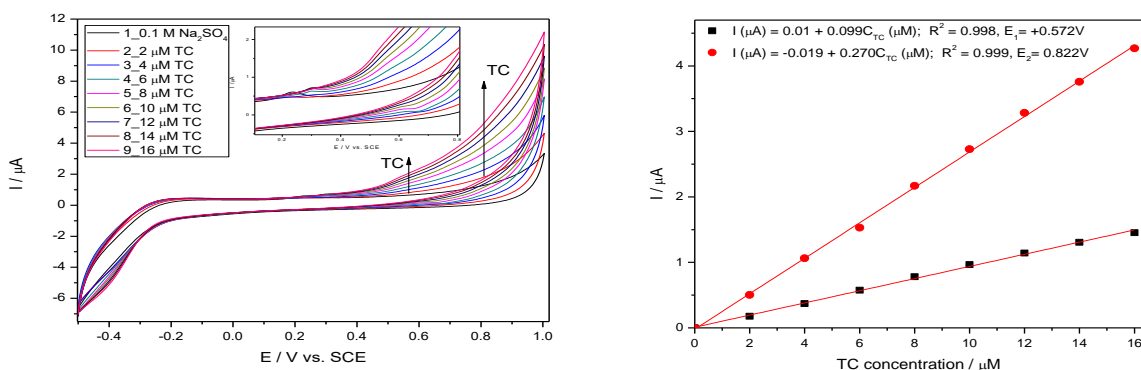
(a)
(b)

Figure 1. (a) Cyclic voltammograms recorded on GR/BDD electrode in 0.1 M Na$_2$SO$_4$ supporting electrolyte (curve 1) in the presence of 2–16 μM DCF (curves 2–9), at a potential scan rate of 0.05 V·s^{-1} in a potential range: -0.5 to +1V/SCE; (b) Calibration plot of the current vs. DCF concentration of the CVs recorded at E$_1$ = -0.110 V/SCE, E$_2$ = +0.540 V/SCE, E$_3$ = +0.150 V/SCE and E$_4$ = -0.140 V/SCE.

3.1.2. Individual detection of tetracycline (TC) by CV

The electrochemical behaviour of TC on GR/BDD electrode was studied by CV and the results are presented in Fig. 2. By testing the GR/BDD electrode in the individual detection of tetracycline, the oxidation process of TC starting later vs DCF, the first potential value of +0.530V/SCE, and the second at +0.822 V/SCE. Also, the sensitivities of 0.092 μA·μM^{-1} and 0.270 μA·μM^{-1} was obtained for TC detection at the potential values of +0.572 V/SCE and +0.822 V/SCE.
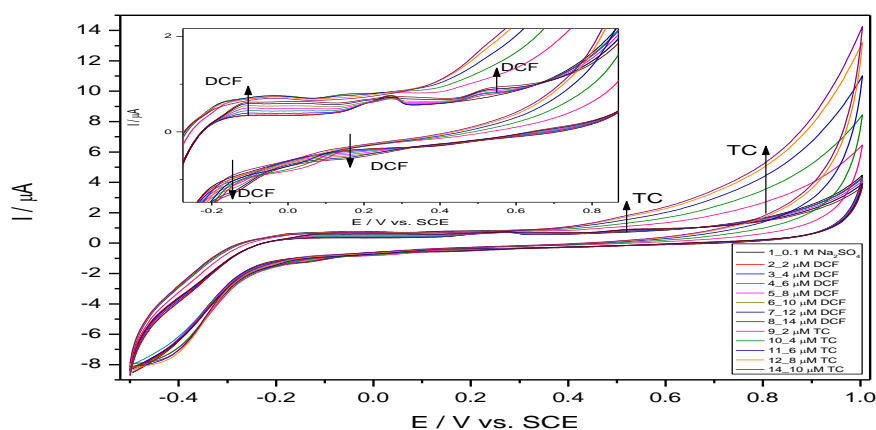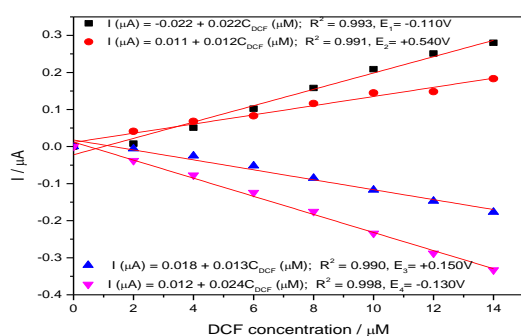

(a)
(b)

Figure 2. (a) Cyclic voltammograms recorded on GR/BDD electrode in 0.1 M Na$_2$SO$_4$ supporting electrolyte (curve 1) in the presence of 2–16 μM TC (curves 2–9), at a potential scan rate of 0.05 V·s^{-1} in a potential range: -0.5 to +1 V/SCE; (b) Calibration plot of the current vs. TC concentration of the CVs recorded at E$_1$ = +0.572 V/SCE and E$_2$ = +0.822 V/SCE.

### 3.1.3 Simultaneous detection of DCF and TC by CV

Considering the different behaviour of both target analytes, DCF and TC, related to the potential values for their oxidation, the simultaneous or selective determination can be developed by simple CV by selection of the potential range. For the whole potential range from -0.5 to +1 V/SCE, the simultaneous detection can be achieved, at about -0.110 V/SCE for DCF and at the positive potential values of +0.530 and respective, +0.822 V/SCE for TC.

(a)

(b)
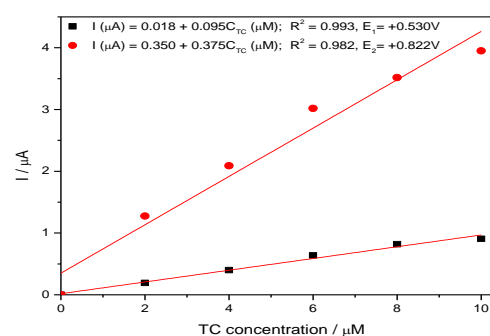
(c)

Figure 3. (a) Cyclic voltammograms recorded on GO/BDD electrode in 0.1 M Na₂SO₄ supporting electrolyte (curve 1) in the presence of of 2–16 µM DCF (curves 2–8), and of 2–10 µM TC (curves 9–14) in a potential range: -0.5 to +1 V/SCE; (b) Calibration plots of the current vs. DCF concentration of the CVs recorded at E_1 = -0.110 V/SCE E_2 = +0.540 V/SCE, E_3 = +0.150 V/SCE and E_4 = -0.130 V/SCE; (c) Calibration plot of the current vs. TC concentration of the CVs recorded at E_1 = +0.530 V/SCE and E_2 = +0.822 V/SCE.

Table 1: Electroanalytical parameters obtained for individual and simultaneous detection of diclofenac and tetracycline on GR/BDD electrode using CV technique.

Type	Analyte	E / V vs. SCE	Sens. (µA/µM)	R^2	RSD [a] (%)	LOD [b] (µM)	LOQ [c] (µM)
Individual	DCF	p.a.-0.110	0.021	0.993	0.745	0.359	1.19
		p.a.+0.540	0.013	0.993	0.735	1.25	4.28
		p.c.+0.150	0.014	0.993	1.12	0.934	3.11
		p.c.-0.140	**0.025**	0.998	0.780	**0.870**	2.88
	TC	p.a.+0.572	0.092	0.998	1.99	0.43	1.42
		p.a.+0.822	**0.270**	0.999	1.58	**0.240**	0.800
Simultaneous	DCF	p.a.-0.110	0.022	0.993	1.19	0.55	1.83
		p.a.+0.540	0.012	0.991	0.70	1.32	4.41
		p.c.+0.150	0.013	0.990	1.11	1.00	3.35
		p.c.-0.130	**0.024**	0.998	0.746	**0.850**	2.84
	TC	p.a.+0.530	0.095	0.993	1.39	0.411	1.37
		p.a.+0.822	**0.375**	0.982	1.57	**0.200**	0.658

p.a.- anodic peak; p.c.- cathodic peak; a Relative standard deviation; b The limit of detection; c The limit of quantitation.

The results obtained on GR/ BDD electrode for individual and simultaneous detection of diclofenac and tetracycline by employing cyclic voltammetry technique are gathered in Table 1. The detection experiments for diclofenac detection were conducted in the presence of tetracycline, because the signal for diclofenac detection is lower. The individual and simultaneous detection of the target analytes on the GR / BDD electrode was achieved, the best performances in relation with the sensitivity, the limit of detection were achieved for the tetracycline detection, which can be selectively detected in the presence of DCF at more positive potential values. Also, DCF can be selectively detected at negative potential value, which is possible due to the presence of graphene.

Conclusion

Based on the above-presented results it can be concluded that GR/BDD modified electrode is very promising for the simulataneous/selective detection of diclofenac and tetracycline in water. The best performances in relation with the limit of detection and limit of quantification was achieved for TC detection.

Acknowledgements

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