Electrochemical Evaluation of Catalytic Effect of Aluminum in Oxidation the Paracetamol in Human Blood

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The reactivity of paracetamol (Pa) using the carbon paste electrode (CPE) modified by the aluminum (CPE-Al) was reported. The working electrode was prepared by mixing the aluminum with the carbon powder. The optimal potential window was selected from -1.7 V to 1.7 V. The effect of parameters such as pH, scan rate, accumulation time and concentration were affected by cyclic voltammetry (CV) and square wave voltammetry (SWV). The optimal preconcentration time is 8 minutes. The reactivity of Pa on the electroanalysis detector was characterized by the appearance of the anodic peak at 0.25 V in a solution of sodium sulfate (0.1 M, pH 7). The calculated limits of detection and quantification have been $8.28 \cdot 10^{-9}$ and $2.74 \cdot 10^{-8}$ mol L^{-1}, respectively. Then relative standard deviation (RSD) at $2.0 \cdot 10^{-5}$ mol L^{-1} Pa concentration was 4.08 % for nine repetitions. The analytical application was carried out in the detection of Pa in human blood with satisfying results.

Keywords: electroanalysis, electrode, paracetamol, cyclic voltammetry, square wave voltammetry, human blood

Acetaminophen or paracetamol is an analgesic identical to acetylsalicylic acid, does not contain gastric irritation and anticoagulant characteristics. It is more used as an active ingredient in the preparation of the drug. Pa based medicines relieve headache, rheumatic pain and all the ills of everyday life [1, 2]. Pa is very powerful in reducing the fever's high temperatures, especially the flu and colds [3]. Pa is used in the treatment of dysmenorrhea, neuropathy and sciatica [4-6]. The main disadvantage of paracetamol is the respiratory problem and the hepatic toxicity of the toxic substance produced in the liver by the cytochrome CYP2E1 [7]. The toxic influences of Pa during overdoses are well known [8], while the reactions of febrile have decreased significantly. Pa should not be recommended at the time of vaccination because the antibody responses of many vaccine antigens have been reduced [9], The usual use of Pa in late pregnancy may increase the danger of breathing [10]. The utilize of Pa in children of 6 to 7 years leads to an increased danger of syndromes of rhinoconjunctivitis and asthma [11]. Thus, the development of an easy, simple, less expensive, precise and sensitive analytical technique for Pa analysis is of great importance. Several methods have been used for Pa analysis such as HPLC, spectrophotometry, capillary electrophoresis [12-16], HPLC-SM [17], spectrofluorometry [18], TLC [19] and micellar electrokinetic capillary chromatography [20,21]. While, these techniques have the disadvantages of the long analysis time, more expensive, pre-treatment of the samples, the sensitivity and selectivity showed by electroanalysis. PA can be electrochemically oxidized, its analysis by electrochemical sensors and techniques has caused significant importance in the last decades [22-24]. Electrochemical techniques use carbon modified electrodes, such as Carbon Paste Electrode Modified with Heavy Metals [25], Carbon Paste Electrode Modified with clay [26], Natural Phosphate Modified Carbon Paste Electrode [27]. The modified electrodes of carbon nanotubes have taken a lot of attention in recent decades. An article of this analysis using carbon nanomaterials has been published in the bibliography [28]. The vitreous carbon electrodes modified with fullerene [29] were used for Pa analysis. A sensitive voltammetric analysis of Pa by adsorption was performed by a pyrolytic graphite electrode [30]. In this work, we characterize the development of an analysis technique for the Pa analysis by SWV and CV on the CPE-Al surface. The electroanalysis method is simple, easy, fast, sensitive and reproducible.

Materials and methods

Apparatus and reagents. The cyclic voltammetry (CV) and square wave voltammetry (SWV) methods were made by a voltalab potentiostat (model PGSTAT 100) controlled by the electrochemical data processing software during the analysis (voltalab master 4 software). The electroanalysis compartment was operated with three electrodes: a CPE-Al working electrode, a reference electrode (saturated Calomel

electrode) and an auxiliary electrode (platinum electrode). The pH meter (Radiometer Copenhagen, PHM210, Tacussel and French) was utilized to adjust the pH of the medium. Pa, Al_2O_3 and Na_2SO_4 were bought from Sigma-Aldrich. The pH was adjusted by sulfuric acid or potassium hydroxide. Distilled water was used to prepare the aqueous solutions in all the work. All experiments were realized at 25°C.

Preparation of the working electrode and procedure. CPE-Al was made by mixing the desired percentage of Al and carbon graphite in the presence of paraffin oil (binder). The body of CPE-Al was a cylinder tightly filled with a mixture of paste and aluminum. The area of this electrode is 0.1256 cm^2. The electrical contact was ensured by a carbon bar.

Different supporting electrolytes were tested such as Na_2SO_4, K_2SO_4, H_2SO_4, NaOH, KCl, and NaCl. The excellent electroanalysis responses were obtained by Na_2SO_4 (0.1 M, pH 7). The working procedure consists in measuring the electrochemical responses at the CPE-Al surface in the presence of Pa. An amount of Pa was added to the electroanalysis cell containing 20 ml of sodium sulfate as an electrolytic medium. The CV and SWV methods were recorded between -1.7 V and 1.7 V. The excellent analysis conditions were determined by measuring the peak current oxidation as a function of the parameters. Electrochemical analyses were obtained at 25 °C.

Results and discussion

Voltammetric analysis of Pa

Fig. 1 and 2 show the (CVs) and the (SWVs) recorded between -1.7 V and 1.7 V on the surface of CPE and CPE-Al. It seems that the CVs and SWVs have different forms, showing that the CPE surface was effectively modified by the aluminum. The electroanalysis responses of the CPE and CPE-Al toward Pa oxidation were studied by CV and SWV in 0.1 M Na_2SO_4 (pH 7) containing $2.0 \cdot 10^{-5}$ mol L^{-1} of Pa. No peak is observed in the case of CPE (Fig. 3a and 4a). Figures 3b and 4b show the anodic peak at about E_{pa} = 0.25 V. The CPE-Al exhibited an excellent electrocatalytic oxidation of Pa compared to CPE. According to this study, scheme 1 shows the Pa oxidation.

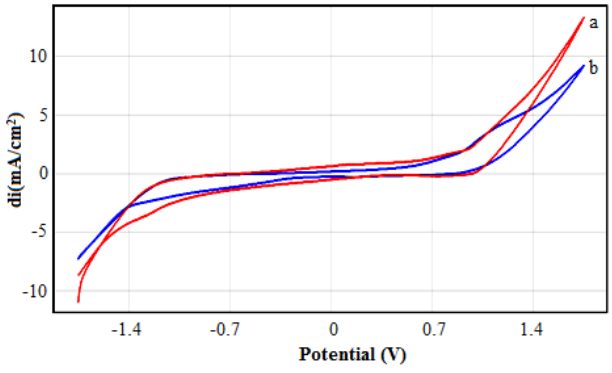


Fig. 1. CVs recorded on the CPE (a) and CPE-Al (b), 0.1 M Na_2SO_4, pH 7, 100 mV s^{-1}.

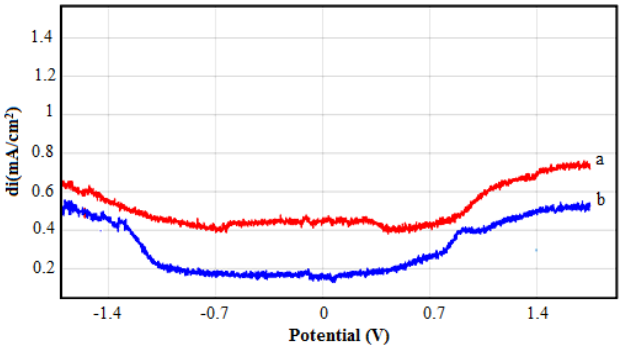


Fig. 2. SWVs recorded on the CPE (a) and CPE-Al (b), 0.1 M Na_2SO_4, pH 7.

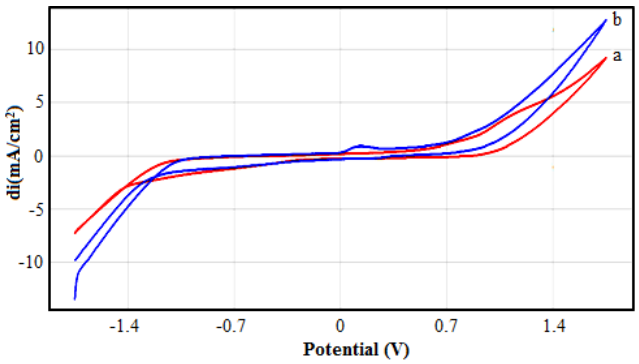


Fig. 3. CVs on the CPE (a) and CPE-Al (b) in the presence of Pa ($2 \cdot 10^{-5}$ mol L^{-1}), pH 7, 100 mV s^{-1}, preconcentration time = 8 min.

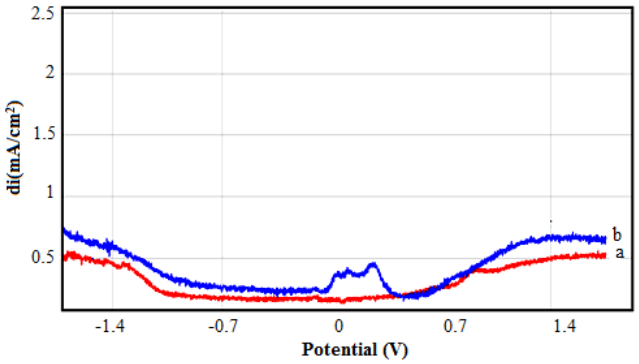
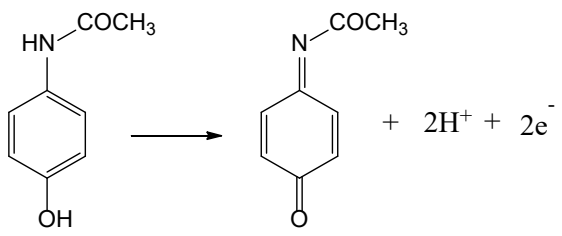


Fig. 4. SWVs on the (a) CPE and (b) CPE-Al, Pa ($2 \cdot 10^{-5}$ mol L^{-1}), pH 7.



Scheme 1. Oxidation reaction of Pa.

Influence of preconcentration time and % Al

This electrochemical study was carried out by the CV method. The electroanalysis parameters were optimized in 0.1 M Na_2SO_4 (pH 7) containing $2.0 \cdot 10^{-5}$ mol L^{-1} of Pa.

The increase of the modifier's loading (from 2 to 40 % by weight of carbon paste) affects the Pa electroanalysis at the CPE-Al surface represented in Fig. 5. The peak current of Pa increases with the increase of the aluminum until 8 %, from 8 to 15 the current remains stable, after 15 % the current decreases. Hence an 8 % of the ratio by weight has been used in this work.

The influence of the accumulation time on the voltammetric measurements was studied. Fig. 6 represents an increase in the current intensity as a function of accumulation time during the first 8 minutes. Another increase in accumulation time does not increase Pa at the CPE-Al surface, which produces stability in the peak current oxidation. This phenomenon is attributed to the saturation of the CPE-Al surface by adsorbed Pa. Hence 8 minutes was used in all the experiments. Other experimental investigate, the optimal electroanalysis parameters to perform the Pa detection was found to be 30 mV s^{-1}, 110 ms, 150 mV, 180 ms for the step, pulse, width, and period, respectively.

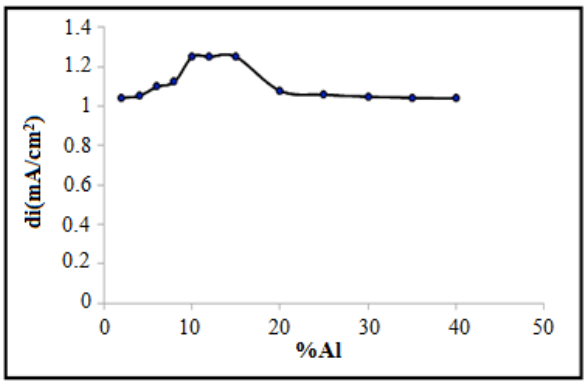


Fig. 5. Influence of % Al in presence of $2 \cdot 10^{-5}$ mol L^{-1} Pa in 0.1 M Na_2SO_4 at the CPE-Al.

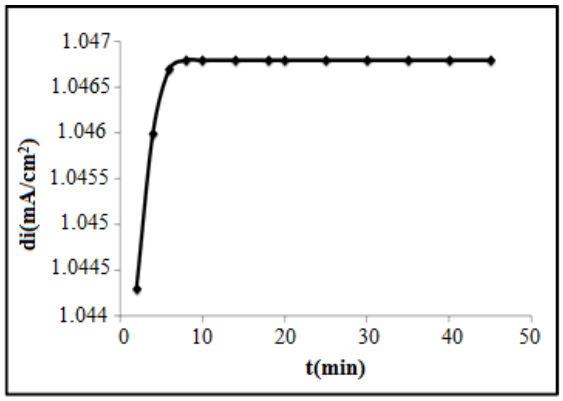


Fig. 6. Influence the accumulation time in presence of $2 \cdot 10^{-5}$ mol L^{-1} Pa at the CPE-Al surface on the peak current oxidation.

Influences of scan rate and pH

The influences of the scan rate and pH on the oxidation peak current of Paracetamol were studied on the CPE-Al surface under the concentration of $1.5 \cdot 10^{-5}$ mol L^{-1} Pa in 0.1 M Na_2SO_4 (pH 7). The oxidation peak current of Pa increased by increasing the scanning rate (Fig. 7). The relationship of oxidation peak current and scan rate was linear when the scan rate increased from 40 to 120 mV s^{-1} (Fig. 8).

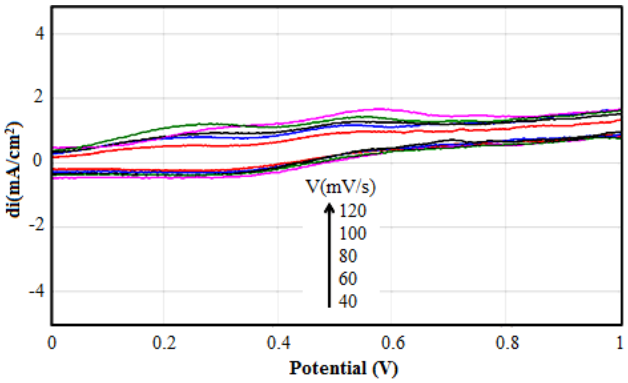


Fig. 7. CVs obtained on the CPE-Al surface in presence of $1.5 \cdot 10^{-5}$ mol L^{-1} Pa at scan rates from 40 to 120 mV s^{-1}.

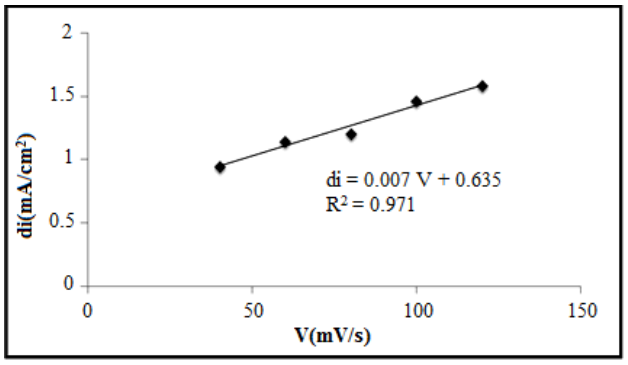


Fig. 8. Variation of the current density as a function of the scanning rates.

The adsorption phenomenon suggested a diffusion-controlled process at the CPE-Al surface. The influence of buffer pH on CV responses of the CPE-Al was further studied in the pH range from 2 to 12 and well-defined CV curves were observed (Fig. 9A). Therefore, pH 7 is the better electrocatalytic activity of the working electrode toward Pa oxidation (Fig. 9B). Also, the increase in pH values moves the oxidation potentials towards the low values (Fig. 9C).

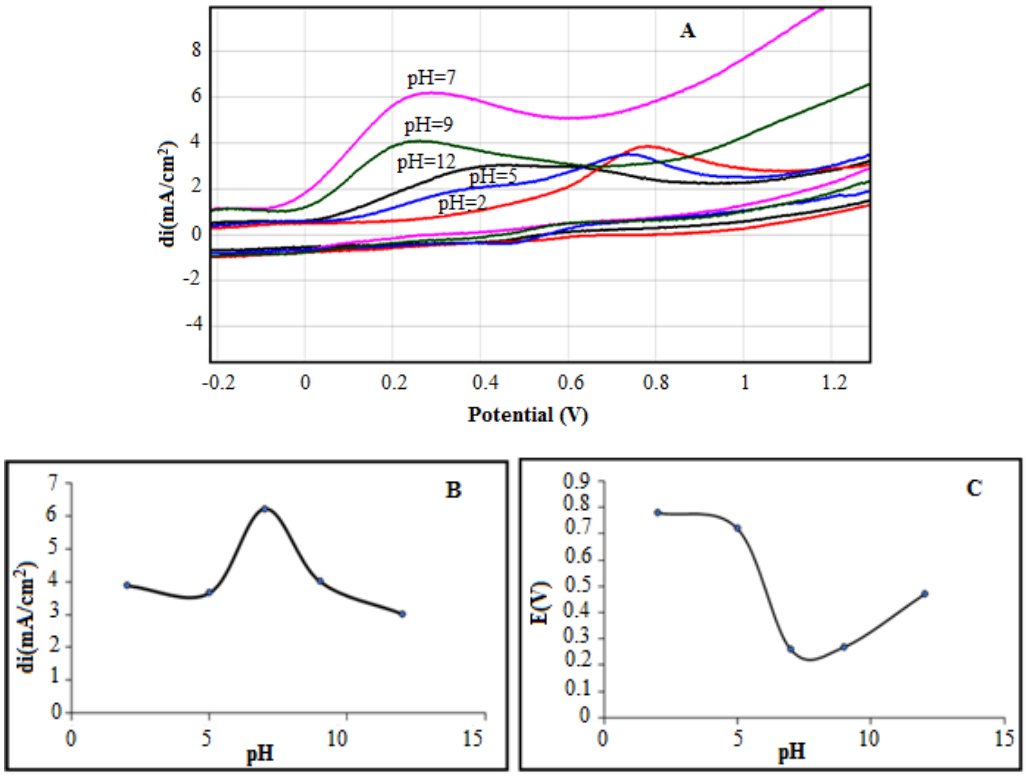


Fig. 9. (A) CVs, (B) current density and oxidation potential recorded for different pH values at the CPE-Al surface.

Calibration curve

The calibration curve was determined for Pa underneath optimum experimental conditions. Fig. 10 and 11 show the CVs and SWVs, respectively, recorded on the CPE-Al between $6.0 \cdot 10^{-5}$ and $8.0 \cdot 10^{-4}$ mol L^{-1} of Pa. The anodic peak current increases with the increasing of Pa concentration. Fig. 12 shows the linear relationship between the peak current versus the Pa concentration on the CPE-Al surface. The reactivity of the CPE-Al surface towards the Pa electrochemical analysis is well-improved thanks to the manganese. The detection limit (DL) and quantification limit (QL) were calculated on the oxidation peak current by the following equations: DL = 3 s/m, QL = 10 s /m (s: Standard deviation of the peak currents nine runs; m: Slope of the calibration curve).

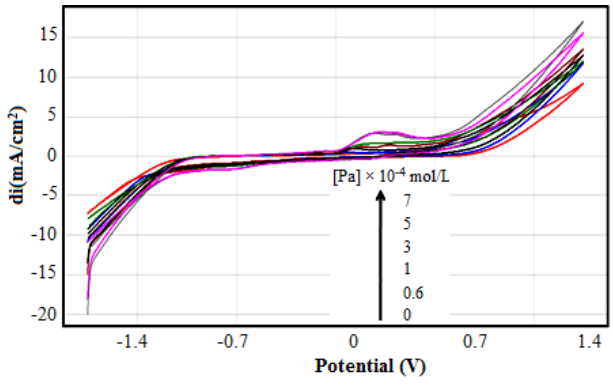


Fig. 10. CVs for different concentrations of Pa at CPE-Al in 0.1 M Na_2SO_4 pH 7, 100 mV s^{-1}.

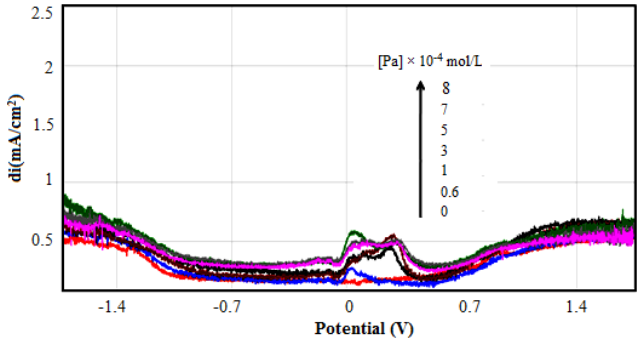


Fig. 11. SWVs for different concentrations of Pa at CPE-Al in 0.1 M Na_2SO_4 pH 7.

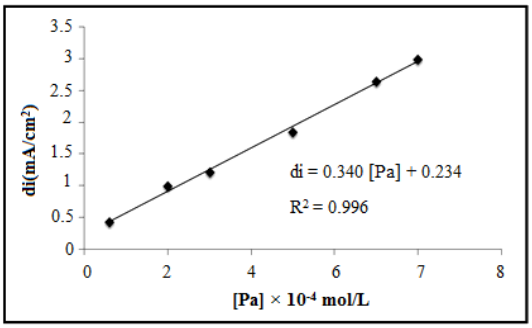


Fig. 12. The curve of peaks current versus the added concentration of Pa.

The DL and QL have been calculated as $8.28 \cdot 10^{-9}$ mol L^{-1} and $2.74 \cdot 10^{-8}$ mol L^{-1}, respectively. The RSD for nine measurements has been calculated

as 4.08 % for Pa concentration of $2.0 \cdot 10^{-5}$ mol L^{-1}. The DL calculated by CPE-Al is comparable to those provided by the previous electrodes recapitulated in Table 1 [31-36].

Analytical application

The CV method was used to determine the paracetamol by CPE-Al in human blood. Then, the calibration plot of the paracetamol in human blood under optimized conditions is linear with an excellent correlation coefficient ($R^2 = 0.9952$) (Fig. 13). The analytical application was carried out by adding a known concentration of Pa in the solution of human blood to confirm the practicability of this electroanalysis method. Consequently, the DL obtained is $9.55 \cdot 10^{-9}$ mol L^{-1}. The RSD calculated is 5.11 % after nine measurements in solutions of $3.0 \cdot 10^{-5}$ mol L^{-1}. This shows the possibility to detect Pa in human blood samples.

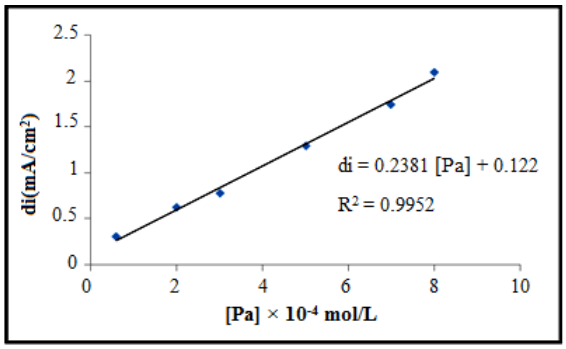


Fig. 13. Calibration curve between peak currents and Pa concentration under optimum conditions.

Table 1. Detection limit of various electrodes for Paracetamol.

Modified electrode	Analytical technique	Detection limit	Epa (V)	pH	Ref.
A nanogold modified indium tin oxide electrode	DPV*	1.8×10^{-7} mol L^{-1}	0.11	7.2	[31]
MgB_2 microparticles modified glassy carbon electrode	CV	3×10^{-7} mol L^{-1}	0.6	6	[32]
Nafion/TiO_2-graphene modified glassy carbon electrode	CV	2.1×10^{-7} mol L^{-1}	0.575	7	[33]
Glassy carbon electrode	DPV	3.69×10^{-7} mol L^{-1}	0.6	4.51	[34]
Boron-doped diamond electrode	DPV	4.9×10^{-7} mol L^{-1}	0.8	4.5	[35]
Aluminum electrode modified by thin layer of palladium	CV	5×10^{-5} mol L^{-1}	0.6	6	[36]
CPE-Al	SWV	8.28×10^{-9} mol L^{-1}	0.25	7	Present work

*DPV: Differential pulse voltammetry.

Conclusion

At the surface of CPE-Al, Pa can produce an irreversible anodic peak at 0.25 V in 0.1 M Na_2SO_4 (pH 7). The CPE-Al exhibits excellent electrocatalytic performance toward the oxidation of Pa. The catalytic evaluated was carried out by cyclic voltammetry. So, to obtain the detection limit of Pa, the cyclic voltammetry method has been used to detect Pa in aqueous media. The CPE-Al is characterized by excellent adsorption of Pa. The linearity between the oxidation peak current and the Pa concentration was linear in the range from $6.0 \cdot 10^{-5}$ to $8.0 \cdot 10^{-4}$ mol L^{-1}. The DL is $8.28 \cdot 10^{-9}$ mol L^{-1}. Besides, the results indicated the feasibility to detect Pa in real samples such as human blood. This method is fast, simple, sensitive, less expensive and reproducible.

Conflicts of Interest

The authors declare no conflicts of interest.

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