



Role of analytical chemistry techniques in carbon paste electrodes: A review

Ali I. Khaleel¹, Omar Salih Hassan²

¹Department of Chemistry, College of Science, Tikrit University, Tikrit, Iraq.

²Department of Chemistry, College of Education of Pure Science, Tikrit University, Tikrit Iraq

Abstract

In this review is given deal with the carbon paste electrodes and its applications in electrochemical analysis. Many carbon pastes electrodes modified were studied. The major importance in this review is to a simple explain about this form of electrodes (carbon paste electrode) which were applied it for the determination of several kind of material in different samples by studied the slope, correlation coefficient, response time, lifetime and statistical values such as: relative standard deviation, relative standard error, and recovery.

©2020 ijrei.com. All rights reserved

Keywords: Carbon paste electrode, Potentiometric, Drug determination, voltammetry.

1. Introduction

Among the most common carbon paste electrode types, is called "Carbon Paste Electrodes (CPEs)", which have been used extensively in electro research, most of all because of such exciting possessions as chemical inertia, little price, apposite and wide-ranging of potentials for a various application of detection and sensing. The appliance of operation for the carbon paste electrodes depended on the quality of the modernizer substances used for selectivity imports against the target species[1,2].Such chemically modified electrodes for carbon pastes own numerous benefits by use ion selective electrode with polymeric membrane counting easiness of preparation, low resistance to ohms, ability of renew, little background assistances, no need any internal solution, with steady response[3,4].For the determination of different cations [5], anions [3,6,7] and biologically important molecules [4,8,9], some of carbon paste electrodes chemically modified potentiometric have been experimented. Modified carbon electrodes were used widely in various electro-analytical methods as selective and sensitive sensors. A mong the different mediators used for modifying the electrodes such as solid metal hexacyanoferrates (MHCFs) owing to its excellent electron transfer properties, they were used as an effective modifier. So several cations have been used as a transition metal to construct MHCF modified electrodes for example using hexacyanoferrate. Its fit to a specific set of heterogeneous carbon electrodes

[10,12].Carbon paste electrodes represented by a mixture which prepared from an appropriate liquid binder crowded into a fittingly fabricated electrode body and powder of carbon(graphite) [13,14]. These electrodes are extensively used principally for voltammetric measurements because of the characteristics and many advantageous possessions; though, carbon paste-constructed sensors are similarly applicable in potentiometry, coulometry, and amperometry. In the main the reason why carbon paste electrodes continue to be popular can be seen mainly because carbon pastes are specifically appropriate for preparing an electrode substantial with chosen structure with pre-determined properties, and simply attainable at least prices, this way, electrodes are mostly considered as very selective sensors to be used for organic and inorganic electrochemistry. Choosing components from carbon paste their consistency and reciprocal relationship in the mixture in addition the method of formulation of carbon pastes and their optimum homogenization—all these aspects determine the resulting CPE behavior. Practical experience has shown that also before use, treatment of CPEs even now equipped can play a very influential role. Properties of electrochemical for different kinds of CPEs can later be predicted just nearly and its more detailed characterization requires adequate test measurements. Research of Carbon paste electrodes represents an experimental, almost empirical method that is

Corresponding author: Ali I. Khaleel

Email Address: Omarchem702@gmail.com

<https://doi.org/10.36037/IJREI.2020.4503>.

particularly useful in characterizing freshly prepared carbon paste. Testing procedures include experiments that enable all essential physico-chemical and properties of electrochemical for carbon pastes to be defined. Furthermore, the methods chosen for evaluating the measurement will also help to disclose certain unique characteristics of individual carbon paste electrodes types. In some sides, measurements for the test may be similar or equivalent to those prescribed for other electrodes (such as: voltammetric studies of possible limitation and background currents, ground feature investigations use reaction kinetics, measured reproducibility, etc [14,16]. As well the aim and reason for the description of an electrode are clearly analogous-finding the preference of electrode for a given reason or, finally, to suggest an appropriate use of an electrode in accordance with its parameters verified through careful testing. It is characteristic of carbon paste based electrodes that their testing often requires different steps and can require even entirely new procedures that, as a whole are barely applicable to other electrode types.

2. Carbon paste with classification

2.1 Common carbon paste types- electrodes

Concerning traditional carbon paste blends with two key constituents, it is conceivable to recognize the current structures as per three explicit criteria:(i) the physicochemical character of the binder,(ii) the status of whether the particular carbon is changed, and(iii) consistency.

2.2 Special carbon paste forms dependent electrodes

2.2.1 Electro-active Electrodes for carbon paste

A group of carbon paste – based electrodes performing first of all in its classic formula in the middle-1970s, appearing firstly typical of community carbon paste – based electrodes [17-20], but the predecessors were largely similar a decade ago, or even mostly identical [21], consist of mixture of carbon paste with qualitatively distinct composition. In the CPE configurations, specifically a strong inorganic electrolyte, for example, concentrated arrangements of mineral acids or basic hydroxides, replaces the at first protecting and synthetically dormant sticking material [22].

2.2.2 Solid, solid comparable, carbon paste electrodes and pseudo

It isn't shock that the expanding assortment of carbon paste has also motivated numerous researchers to detail, Further advancement of related blends, and test, In which traditional oils have been supplanted by different fasteners. A significant number of the terminal substrates coming about had a somewhat thicker quality than that of conventional CPEs (be like nutty spread as endorsed by Adams [23]. Here, the individual model can be given quickly when the meaning "strong" or strong comparative" in CPE is authentic and originates from the creators' papers, except for a couple of example. The most seasoned models of as-CPE

were those which purposefully consolidated graphite powder with (I) elastic of silicone [24,25,26–27], this had accomplished their last precision after chilly vulcanization, and was suggested for both hydrodynamic estimations and fixed. Explicit s-CPE worked as sensors of amperometric or finder were rather made of (ii) emphatically atomic polyvinyl chloride [25], (iii) chloroprene elastic alkyl phenyl resin (ration as 1:1) [27], or identical (iv) butadiene elastic [28]. Different sorts of s-CPEs were built on (v) wax of paraffin [29] or (vi) wax of ceresin [30], which can be basically melted (together under 100°C) [31], changed with powder of graphite, and rather it left for good solid scatterings to chill. As of now, wax impregnated electrodes might be named as the s-CPEs utilized most commonly [32,33,34,35–36]. A strong – like paste blend produced using natural solvents has exhibited shockingly solid opposition such as (vii) poly (chlorotrifluoroethylene) oil (or wax, separately), known under a trademark Kel-F® [37,38,39]. It is expressed that the individual indicators might be utilized in the versatile procedure of HPLC containing up to 70 percent. Despite the fact that to endeavors in looking for new substitute folios, there is a progression of related reports [40-41]. On "pseudo-carbon paste terminals" (p-CPEs) whose structure comes up short on the typical fluid moiety, it is subbed by a polymer. Specifically, such permeable p-CPEs can be produced by blending polystyrene microspheres (as a format) and powder of graphite pyrrole (utilized as a monomer, the glue – like blend really shaped). The last is expelled after catalyzed polymerization to yield the subsequent permeable structure (with pores of 2-5 microns in breadth) Reportedly [40] the zone of surface, for example, (n)P-p-CPE is enormously extended (from ca. 10 up to 60 m² • g⁻¹), benefit like conventional CPEs-from a brisk and quick arranging (when not requiring restricting agents),fast conservation and recovery ,albeit for the most part emphatically hydrophobic, bringing about solid inclination for particular conglomeration of lipophilic natural compounds[42] .

2.2.3 New Electrodes for Carbon Paste

Indeed, every CPE prepared from materials previously classified as “new binders” or “new types of carbon” [43,44,45,46,47,48,49,50,51,52,53], could also be regarded as new CPEs. However, in such situations, the respective electrodes constitute more or less the first designs that have occurred in a few instances so far and often only experience simple characterization, that is without broader presence and usual applications. In this group, another quintet or reports may be included [53]. On as of late created carbon paste – developed electrode ordinarily alluded to as carbon paste film electrodes (CPFes) for which relating structure has been diminished to an extremely slim film/layer of carbon (glue) associated with a reduced terminal casing, exactly, Ni-Cr composite [54,56,57]. The glue itself is both "very flimsy film" (STF; accomplished by decorating a blend of two customary segments (and the going with electrode known as STF-CPE) or comprising completely from substitute CP-parts, which is the situation for two blends MW-CNTs +(RT)IL [55,56] and GR + (RT)IL [54], Notwithstanding GR and ionic fluid (of the Q+PF6⁻ type), the last likewise incorporates an extra strong fastener with an organic detecting highlight .The sorts of carbon paste cathodes including:

- Diamond as the base of the Electrodes and Diamond Paste Electrodes.
- Electrodes of Carbon Paste and of Carbon Nanotubes.
- Electrodes of Carbon Paste and of Ionic Liquids.

3. Carbon paste electrodes with some chemistry techniques

In potentiometry Particle particular anode is portrayed as an electrode equipped for delivering a distinction in the electrical potential among itself and a reference terminal, the creation potential for the arrangement is relative to the volume or convergence of the particle picked [55-56]. New particle - particular terminals are centered around membrane by which material exchange happens this material vehicle includes all impartial and charged complex species or straightforward particles and electron which adds to variety in electrostatic potential through membranes [57]. These additionally known membrane possibilities reflect similarly particle creation and outer stage movement. The particle specific electrode can gauge the movement and selectivity of a given particle independent of another particle in solution [58-59]. Can be characterized Ion-particular electrode to certain sorts as indicated by the creation and sort of the responsive film for glass terminals fluid membrane electrodes, gas detecting electrodes, strong state electrodes, covered wire terminals, chemical substrate electrodes [60]. Potentiometric distinguishing proof concentrated on explicit particle electrodes gives the upsides of speed and simplicity of arranging, fast reaction time, reasonable selectivity, wide straight dynamic run, ease online estimation. The wider utilized electrodes of strong membrane are the plasticized poly (vinyl chloride), (PVC) terminals which depend on development – medication and counter – particle partners, In the readiness of the film electrode, the shaped particle – partner was then utilize along with PVC and a proper plasticizer. Fluid membranes, then again, are shaped from immiscible fluids which selectivity tie certain particles, the fluid particle exchanger can be put away in a cracked strong help that isolates the inside arrangement of the fluid terminal from the preliminary arrangement [61]. Ion – specific electrodes were broadly utilized in pharmaceutical compound location [62-65]. The structure of carbon paste takes into account the order of CPEs as particle – particular fluid film type electrodes from the point of view of balance potentiometry. The gluing fluid by and large has great capacity to separate non-separated feeble corrosive, unbiased metal chelates or particle partners against impartial electro dynamic species. At that point, the capacity of an electrode including such a natural dissolvable concentrate is essentially constrained by ionic association at the interface between the natural period of the terminal and the example arrangement, coming about in the alleged Donnan capacity [66]. Carbon paste based particle specific terminals (CPISEs) have been reported and used to assess a few particles and medications, for example, four particle exchangers for new fluoroborate CPISEs and perchlorate were readied, that discover their application in the two anions direct potentiometric judgments, notwithstanding observing sensors for potentiometric particle pair arrangement based titration[67], the particle blending standard was correspondingly utilized in the titrations of complex

trivalent thallium anions [68] or components setting up heteropolyanions.[69,70]. And in the voltammetric stripping study, the choice of the key constituents for preparing the carbon paste was exceptionally moderate and no endeavors were made to search for new substitute materials. For most applications, the properties of customary paste blends produced using spectroscopic paraffin oils and graphite were discovered good, for instance electrode which utilized for assurance of follow iron (III) in pharmaceutical compounds [71]. In 1993, new sorts of CPEs presented that contained increasingly polar natural fluid, frequently utilized as plasticizers of polymeric film based particle – particular electrodes. [72]. For model, a CPE containing tricresyl phosphate was seen as perfect for the collection of some lipophilic anions. Some intriguing utilizations of these paste were presented around then in both the stripping voltammetry [73] and stripping chronopotentiometry [74].

About amperometric technique, the primary carbon paste electrode alterations with movies of manganese dioxide allowed to obtain sensors for the assurance of hydrogen peroxide started toward the finish of the 1990s in collaboration with Austrian colleagues [75,77]. Nevertheless, it appeared to be increasingly doable to move all the experience gained with these CPE-based sensors to their simple screen-printed arrangements for use in method utilizing stream infusion investigation [78]. These sensors permitted the identification of hydrogen peroxide through either intervened decrease or interceded oxidation, likewise, in blend with a legitimate biocatalyst (glucose oxide was utilized in the underlying analyses) they filled in as fundamental units in the assembling of the coordinating biosensors [79-80] a related biosensor relied upon sarcosine oxidase was too reported [81]. There has additionally been investigation of adjustment with other metal oxides. Biosensors with solid properties were as of late acquired when electro impetuses were utilized as modifiers/go between dependent on the oxides of Platinum bunch metals [82-84]. Also contemplated biosensors which were relied upon dehydrogenases.

4. Carbon Paste Structure

Developing carbon paste structure are non-minimized and delicate, and must be put away in unique bodies. A carbon paste holder can be made as a very much penetrated to a short Teflon rod [70] tube from glass [85] or a syringe of a polyethylene [86] loaded up with a paste, which is reached electrically through a directing wire. These makes are exceptionally simple; however, there is one thing that makes them not extremely sensible and that is the need to top off the carbon in experimentations including a successive prohibition of the surface layer for terminal. Monien et al. [87] planned increasingly refined development which going around this tedious technique and Lindquist, [88], who recommended cylinder – driven terminal holders where the necessary amount of the paste utilized may handily be expelled from the electrode body and smoothed or remove, our testing office uses explicit types of home – made cylinder fueled carbon paste holders [89]. Gathering of the particle specific electrode dependent on graphite paste appeared in Fig1.

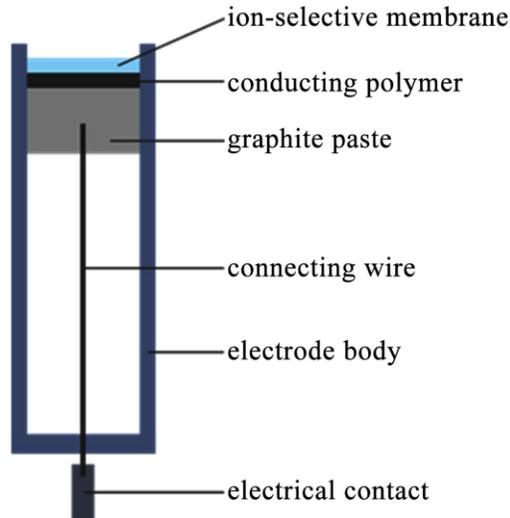


Figure 1: Assembly of the ion-selective electrode based on graphite paste [90]

The investigation network has as of late committed extraordinary consideration regarding making new or imaginative carbon paste electrode holders. Two basic delineations of these practices are appeared in Fig.2 Illustration "1A" shows two forms of the purported carbon paste groove electrode (CPGrE) as atypical CPE design, replicating the planar arrangement of a few screen – printed electrodes. The CPGrE get together comprise of a smaller than normal plastic kaleidoscopic bar with a flat channel for carbon paste filling, a metal contact and extra plastic insert(s) that characterize the electrode surface through its mechanical inclusion/introduction. The entire structure by developed as an electrically warmed electrode (left), reasonable for clump estimations and empowering the affectability of estimations that must be created in still answers for upgrade or as the working terminal for hydrodynamic amperometry, and as the identifier in moving streams (right).

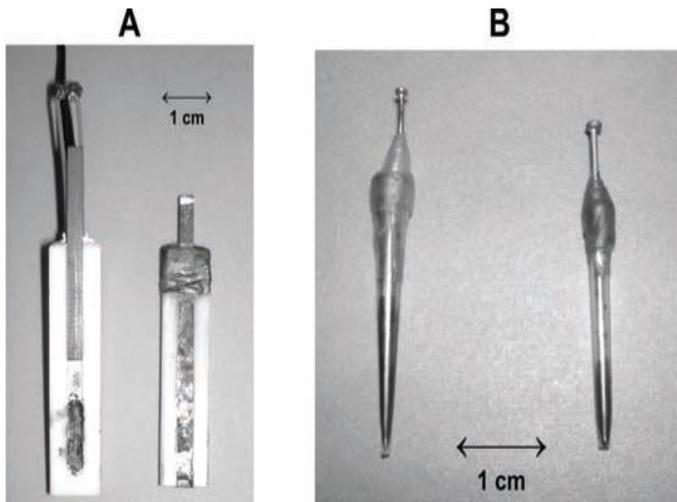


Figure 2: Some novel construction types of electrode holders for carbon paste. [91]

Photo "1B" depict another type of carbon paste mini than usual electrode (CPmE) that can be created from conventional plastic pipette tips, the vertical cutting of which delivers the necessary surface region [91], this minimal size has the advantage of diminishing the utilization of carbon paste(s), and might be cheap by using certain blends from exorbitant carbon nanotubes. Some Studies on Surface modification Properties of Carbon Paste Carbon paste prepared from lipophilic gluing fluids show recognizably hydrophobic nature of their surface, containing the purported dry blends with genuinely low restricting bit content. This hydrophobicity at that point brings about conduct of various composites and redox couples at CPEs being respectably reversible or even absolutely irreversible, while similar materials estimated at common strong electrodes can show reasonable reversibility. In utilizations of voltammetric, unassuming reversibility (or irreversibility) is of model unwanted as the related expected breaking point and hence misshaped or totally covered by more noteworthy foundation flows. Notwithstanding potential changes in the gluing fluid and its substance in the paste, the level of hydrophobicity of CPEs can be decreased by incomplete or complete evacuation of the fastener surface; e.g. by presentation of the carbon paste surface to extraordinary potential temporarily. Beneath these conditions, contingent upon the expected extremity, the outside of carbon particles in changed into hydrophilic useful gatherings f - C=O for instance, - C-O" or - C=OH+ that are fit to repulse the fluid layer of lipophilic. The impact of this surface adjustment, too known as electrolytic actuation (or anodic and cathodic polarization, individually) can be investigated with advantage through relative estimations of dynamic and un enacted CPEs. Cyclic voltammetry of either hydrazinium particle or ascorbic corrosive might be suggested both speak to ordinary irreversible frameworks with "touchy" energy to surface condition at a CPE. A appropriately boundaries, fundamentally exceptionally high initiation potential or its application for longer timeframes may as of now cause excessively "extreme" changes in the terminal surface of the carbon paste joined by increment lingering flows. The at first anticipated valuable effect of the initiation procedure is rather totally nullified [92]. Application of Carbon Paste Electrodes In this paper had been reported the application of carbon paste electrodes to evaluation different materials with using various techniques such as voltammetry, amperometric and potentiometry, Table 1 shown the type of carbon paste electrodes construction for potentiometric measurements.

Table 1: Application of carbon paste electrodes for potentiometric measurements

| Analyte | Type of CPE | Technique | Results | Ref. |
|--|---|---|--|-------|
| Ferricyanide | Modified Glassy Carbon Paste Electrodes | Amperometric and Cyclic voltammetry | Linearity range (M)= 2.5×10^{-7} - 5×10^{-4} and 5×10^{-7} and 5×10^{-7} - 5×10^{-4} Correlation Coefficient=0.9906 and 0.9972 Sensitivity ($\mu\text{A mM}^{-1} \text{cm}^2$)=188 and 99 %RSD=6 and 7 Response Time (sec)=15 | [93] |
| Dopamine | Graphene–chitosan nanocomposite modified carbon paste electrode | Cyclic voltammograms | Linear Equation : $Y=552.38-49.45x$ and $Y=1.81+0.28x$ Correlation Coefficient=0.9911 and 0.9961 | [94] |
| Cadmium in water | Carbon paste electrode modified | Stripping voltammetry | Linear Equation : $Y=31.21X+1.154$ Correlation Coefficient=0.998 PH=5 | [95] |
| Triblock copolymer as directing agent and tetraethyl orthosilicate (TEOS) as silica source | Carbon Electrode | Cyclic voltammetry and electrochemical impedance spectroscopy | BET surface areas of the mesoporous silicas= 913.26 m ² /g and 450.37 m ² /g for SBA-15 and SBA-16 | [96] |
| Nitrate and Ammonium | Solid-Contact Ion-Selective Electrodes Based on Graphite Paste | Potentiometric | Linear range (mol/L)= 10^{-1} - 10^{-6} and 10^{-1} - 10^{-5} Coefficient of determination (R ²)=0.991 and 0.995 Limit of detection (mol/L)= $<10^{-6}$ and $<10^{-5}$ Response time (s)= <15 for both Life time(month)= 6-12 for both | [90] |
| Phenol | Clay- Carbon Paste Electrode Modified | Electrochemical Sensor | Detection limit(mol/L)= 2.041×10^{-5} and 0.952×10^{-6} Coefficient of determination (R ²)=0.853 and 0.882 | [97] |
| Hydrogen peroxide | Ionic liquid modified carbon paste electrode | Voltammetry and Amperometric | Linear range = 35-2000(μM) and 2-30(Mm) Limit of detection (μM)= 15.0 and 2.60 Response time (s)= 20 and 4 | [98] |
| Nitrate in Drinking Water | Carbon Paste Electrode | Cyclic voltammetry | Potential range = +1.0 to -1.0 V (vs. Ag/AgCl). PH=7 Oxidation peak =at +0.14 V (vs. Ag/AgCl) | [99] |
| Folic acid in presence of Dopamine and Ascorbic Acid | Poly(Alanine) MCPE | Cyclic voltammetry | Linear range = 10-40(μM) and 50-80 Limit of detection (μM)= 3.40 and 0.780 | [100] |
| Heavy Metals | Carbon Paste Electrode | Square Wave Voltammetry | Linear Equation : $Y=35.76 [\text{Pb(II)}] (\mu\text{mol l}^{-1})+0.0295$ and $75.23 [\text{Cd(II)}] (\mu\text{mol l}^{-1})+0.075$ Correlation Coefficient=0.9852 and 0.9802 Limit of detection (Mole/L)= 5.7 and 8.24 %RSD=6.8 and 5.0 | [101] |
| Atrazine | Polyaniline Carbon Paste Electrode | Voltermetric and Amperometric | Limit of detection (μM)= 0.3 | [102] |
| Captopril | Multiwall Carbon Nanotubes Paste Electrode | Voltammetry | Limit of detection ($\mu\text{mole/L}$)= 0.1 Sensitivity ($\mu\text{A } \mu\text{mol}^{-1} \text{L}$)=0.0252 Correlation Coefficient=0.994, 0.9967,0.9910,0.9970,0.9951, | [103] |
| phenolic estrogenic compounds | Clay modified carbon paste electrode | Cyclic voltammetry | Linear range(M) = 7.26×10^{-6} - 3.87×10^{-7} Limit of detection (M)= 9.2×10^{-7} Correlation Coefficient=0.9963 | [104] |
| Ascorbic acid | Carbon paste electrode modified with iron(III) ions | Cyclic voltammetry | Linear range(mmolL ⁻¹) = 0.0- 1.4 Equation $I(\mu\text{A}) = 7.6286 [\text{H}_2\text{A}] (\text{mmol L}^{-1}) + 1.9583$ Correlation Coefficient=0.9996 | [105] |
| Nitrite in Water | Carbon paste electrodes Modified Diatomite | Cyclic voltammetry and Amperometric | linear domain(Mm)= 0.0001-0.1 Limit of detection (μM)= 9.10 Sensitivity(mA M^{-1})=9.88 | [106] |
| Methyldopa in Urine and pharmaceutical formulation | Graphene nanosheet paste electrode | Voltammetry | Linear range (mol/L)= 9.0×10^{-8} - 5.0×10^{-4} Limit of detection (mol/L)= 5.0×10^{-8} | [107] |
| Ultra-trace amounts of silver in water | New modified carbon paste | Differential pulse anodic stripping | Linear range ($\mu\text{g L}^{-1}$) =0.001–100 Limit of Detection(ngL^{-1})=1.1 | [108] |

| | | | | |
|--|---|---|--|-------|
| | | voltammetry | %RSD=1.5 %Er= -1.3 | |
| Lead | Tricalcium Phosphate Apatite Modified Carbon Paste Electrode | Square -wave voltammetry | Linear Equation: $Y = 0.0073x + 1.3076$ Correlation Coefficient= 0.906 Limit of Detection(M)= 4.3×10^{-6} | [109] |
| Vitamin C | Carbon Paste Electrode Modified by Multi walled Carbon Nanotube | Square-wave Voltammetry | Limit of Detection(M)= 4.3×10^{-6} PH=5.0 %RE=96-102 | [110] |
| Copper(II) | Etioporphyrin I dihydrobromide Carbon Paste Electrode | Potentiometry | Linear range (moleL ⁻¹) = 1.28×10^{-6} - 1.28×10^{-2} Slope= 30.30 mV per decade Limit of Detection(moleL ⁻¹)= 8.99×10^{-7} Range of PH=4.5-8.5 Response time(sec)= 5 | [111] |
| Anthrone | Cetyl Trimethyl Ammonium Bromide Surfactant Modified Carbon Paste Electrode | Cyclic Voltammetry | Linear range (moleL ⁻¹) = 3×10^{-5} - 5×10^{-5} and 6×10^{-5} - 1.7×10^{-4} Limit of Detection(moleL ⁻¹)= 21×10^{-7} PH=6.5 | [112] |
| Cadmium Oxide | Nanoparticles Modified Carbon Paste Electrode | Cyclic Voltammetry | Linear range (moleL ⁻¹) = 5.0×10^{-8} - 5.0×10^{-6} Cathodic transfer coefficient = 0.40 Electron transfer rate constant(s ⁻¹) = 1.47 Limit of Detection(moleL ⁻¹)= 21×10^{-7} PH=7 | [113] |
| Uric Acid | Carbon Paste Electrodes Modified by Molecularly Imprinted Polymer | Potentiometric Sensor | Linear range (moleL ⁻¹) = 10^{-6} - 10^{-3} Limit of Detection(moleL ⁻¹)= 3.03×10^{-6} % precision= 1.36-2.03 % accuracy= 63.9-166 | [114] |
| Tyrosine | Carbon paste Electrode | Cyclic Voltammetry in a Flow Injection System | Limit of Detection(moleL ⁻¹)= 6.6×10^{-9} pH=7.0 potential scan rate=1 Vs ⁻¹ Accumulation time=0.5s Accumulation potential=-500 mV | [115] |
| As(V) from aqueous solutions | Carbon paste electrode with the pristine bentonite and hybrid material (HDTMA-modified bentonite) | Electrochemical sensor | Linear Equation: $Y = 0.9172x + 0.5863$ and $Y = 0.084 + 10.38$ Correlation Coefficient= 0.9997 and 0.991 | [116] |
| Flavoxate Muscle Relaxant Drug | Carbon paste Electrode | Potentiometry | Linear range (moleL ⁻¹) = 1.39×10^{-5} - 1×10^{-2} and 1×10^{-5} - 1×10^{-2} Limit of Detection(moleL ⁻¹)= 1.39×10^{-5} and 1×10^{-6} Response time(sec)= 5.0-7.0 %Re=97.2-101.0 and 98.1-101 | [117] |
| Tissue O ₂ | Carbon paste Electrode | Cyclic Voltammetry Amperometric | Applied potential(mV)=-650 Sensitivity(nA / μ M) = -1.49 \pm 0.01 Correlation Coefficient= > 0.99 | [118] |
| Antihyperlipidemic Simvastatin in Biological Samples | Carbon Paste Electrode Bulk-Modified with Multiwalled Carbon Nanotubes | Scanning Electrochemical | Linear range (moleL ⁻¹) = 2.4×10^{-7} %RSD=4.8 % Re=99.7 and 99.5 | [119] |
| Copper(II) | Carbon paste Electrode | Differential Pulse Voltammetry | Linear range (nmoleL ⁻¹) = 0.5- 10 Limit of Detection(nmoleL ⁻¹)= 0.237 Correlation Coefficient=0.9997 %RSD=1.42 | [120] |
| Cesium | Modified Carbon Paste Electrode of Cesium | Potentiometric Method | Slope(mV.decade ⁻¹) = 58 ± 0.5 Linear range (moleL ⁻¹) = 1×10^{-6} - 1×10^{-1} Response time(sec)=35 PH=4.0-8.0 Life time(months)=3 | [121] |

5. Conclusions

There are several electrochemical techniques have been described for the recognition of drugs in a variation of tests, due to it is a rapid method for determination the drug levels from biological, food or water samples is required worldwide. Electrochemical sensors modification showed a great increase in current response, stability, selectivity with high sensitivity. This paper discusses primarily several types of electrochemical sensors. Carbon paste electrodes are the economical from of preparation and present easy ways, in addition they as well show the possibility of rapid renewal of the active surface, eliminating the fouling effect. It is fully knowing that an oily binder is used in the preparation of a CPE to make the paste. This mineral oil is an isolating substance ,and perhaps the reason why some kinds the reported little current range .The selection of electrochemical sensors for drug determination should also be have an effect by the kind of real tests used in applications, any of the applications require minimum detection limits ,some need method that is extremely selective and stable, and some require large range of concentrations, though another applications must cover concentration ranges greater than μ molar drug levels.

Acknowledgment

The authors are grateful to Department of Chemistry, College of Sciences, Tikrit University and Department of Chemistry, College of Education for pure Sciences Tikrit University, for the support.

Abbreviation

| | |
|---------|---|
| CPEs | Carbon Paste Electrodes |
| MHCFs | Solid Metal Hexacyanoferrates |
| P-CPEs | Pseudo- Carbon Paste Electrodes |
| CPEFs | Carbon Paste Film Electrodes |
| STF-CPE | Super Thin Film - Carbon Paste Electrodes |
| MW-CNTs | Multi Walled -Carbon nanotubes |
| PVC | Polyvinyl(chloride) |
| CPISEs | Carbon Paste-based Ion-Selective Electrodes |
| GPGRE | Carbon Paste groove Electrodes |
| CPmE | Carbon Paste mini-Electrodes |
| PH | Measure of the acidity or basicity of aqueous solutions |
| %RSD | Relative standard deviation |
| %Er | Relative Error |
| %Re | Recovery |

References

[1] K. Kalcher, J. M. Kauffmann, J. Wang, I. Svancara, K. Vytras, C. Neuhold and Z. Yang, "Sensors Based on Carbon Paste in Electrochemical Analysis: A Review with Particular Emphasis on the Period 1990-1993," *Electro-analysis*, Vol. 7, No. 1, 1995, pp. 5-22.

[2] J. Wang, "Electroanalytical Chemistry," 2nd Edition. Wiley, New York, 2000.

[3] M. N. Abbas, "Chemically Modified Carbon Paste Electrode for Iodide Determination on the Basis of Cetyl- trimethylammonium Iodide Ion-Pair," *Analytical Sciences*, Vol. 19, No. 2, 2003, pp. 229-233.

[4] M. K. Amini, J. H. Khorasani, S. S. Khaloo and S. Tangestaninejad, "Cobalt(II) Salophen-Modified Carbon- Paste Electrode for Potentiometric and Voltammetric Determination of Cysteine," *Analytical Biochemistry*, Vol. 320, No. 1, 2003, pp. 32-38.

[5] M. J. Gissera, M. A. Mendiola, J. R. Procopio and M. T. Sevilla, "Copper Potentiometric Sensors Based on Copper Complexes Containing Thiohydrazone and Thiosemicarbazone Ligands," *Analytica Chimica Acta*, Vol. 385, No. 1-3, 1999, pp. 143-149.

[6] J. Jezkova, J. Musibva and K. Vytras, "Potentiometry with Perchlorate and Fluoroborate Ion-Selective Carbon Paste Electrodes," *Electroanalysis*, Vol. 9, No. 18, 1997, pp. 1433-1436.

[7] M. Shamsipur, A. Soleymanpour, M. Akhond, H. Sharghi and M. A. Naseri, "Iodide-Selective Carbon Paste Electrodes Based on Recently Synthesized Schiff Base Com-plexes of Fe(III)," *Analytica Chimica Acta*, Vol. 450, No. 1-2, 2001, pp. 37-44.

[8] M. N. Abbas and G. A. E. Mostafa, "Gallamine-Tetra- phenylborate Modified Carbon Paste Electrode for the Potentiometric Determination of Gallamine Triethiodide (Flaxedil)," *Journal of Pharmaceutical and Biomedical Analysis*, Vol. 31, No. 4, 2003, pp. 819-826.

[9] K. I. Ozoemena, R. I. Stefan, J. F. Van Staden and H. Y. Aboul-Enein, "Utilization of Maltodextrin Based Enantio selective, Potentiometric Membrane Electrodes for the Enantio selective Assay of S-Perindopril," *Talanta*, Vol. 62, 2004, pp. 681-685.

[10] Kalcher K.: *Electroanalysis* 2, 419 (1990).

[11] Kalcher K., Kauffmann J.-M., Wang J., Švancara I., Vytfas K., Neuhold C, Yang Z.: *Electroanalysis* 7, 5(1995).

[12] Kalcher K., Cai X., Kolbl G., Švancara I, Vytrās K.: *Sb. Ved. Pr., Vys. Sk. Chemickotechnol., Pardubice* 57, 5(1995).

[13] Švancara I., Vytfas K., Renger F., Smyth M. R.: *Sb. Ved. Pr., Vys. Sk. Chemickotechnol., Pardubice* 56, 21(1992/93).

[14] Švancara I., Vytfas K.: *Chem. Listy* 88, 138 (1994).

[15] Adams R. N.: "*Electrochemistry at Solid Electrodes*". M. Dekker, New York 1969.

[16] Hvězďalova M.: *MSc Thesis*. University of Pardubice, Pardubice 1994.

[17] Bauer, D. and P. Gaillochot. "Behavior of carbon pastes containing an electro-active compound (in French)". *Electrochim. Acta*, 1974,19:597-606.

[18] Lindquist, J. " Carbon paste electrode with a wide anodic potential range". *Anal. Chem.* 1973, 45:1006-1008.

[19] Lindquist, J. "A study of seven different carbon paste electrodes". *J. Electroanal. Chem.* 1974,52:37-46.

[20] Gaillochot, P., D. Bauer, and M.-C. Hennion.. Rapid determination of uranium in ores by means of a carbon paste electrode (in French). *Analusis (Bruxelles)*, 1974, 3:513-516.

[21] Barikov, V.G., Z.B. Rozhdestvenskaya, and O.A. Songina. "Phase electrochemical analysis with a carbon paste electrically-active electrode (in Russian). *Zavod. Lab.* 1969 ,(U.S.S.R.) 35:776-778.

[22] Kalcher, K., I. Švancara, R. Metelka, K. Vytrās, and A. Walcarius. "Heterogeneous electrochemical carbon sensors". In *The Encyclopedia of Sensors*, 2006. Vol. 4, Eds. C.A. Grimes, E.C. Dickey, and M.V. Pishko, 1963,11:71-78.

[23] Adams, R.N.. Carbon paste electrodes. A review. *Rev. Polarogr. (Jpn.)*, 1963,11:71-78.

[24] Pungor, E. and E. Szepesvary. 1968. Voltammetric studies with silicone rubber-based graphite electrodes. *Anal. Chim. Acta* 43:289-296.

[25] Stulik, K. and V. Pacakova. 1981. Comparison of several voltammetric detectors for high-performance liquid chromatography. *J. Chromatogr. A* 208:269-278.

[26] Nagy, G., Zs. Feher, and E. Pungor. 1970. Application of silicone rubber-based graphite electrodes for continuous flow measurements: Part II. Voltammetric study of active substances injected into electrolyte streams. *Anal. Chim. Acta* 52:47-54.

[27] Stulik, K., V. Pacakova, and B. Starkova. 1981. Carbon pastes for voltammetric detectors in high-performance liquid chromatography. *J. Chromatogr. A* 213:41-46.

[28] Lee, B.-G., K.-B. Rhyu, and K.-J. Yoon. 2010. Amperometric study of hydrogen peroxide biosensor with butadiene rubber as immobilization matrix. *J. Industr. Engineer. Chem.* 16:340-343.

- [29] Mesarić, S. and E.M.F. Dahmen. 1973. Ion-selective carbon-paste electrodes for halides and silver(I) ions. *Anal. Chim. Acta* 64:431–438.
- [30] Atuma, S.S. and J. Lindquist. 1973. Voltammetric determination of tocopherols by use of a newly developed carbon paste electrode. *Analyst (U.K.)* 98:886–894.
- [31] Crow, D.R. 1975. Voltammetry with the carbon-wax-based electrode. *Proc. Anal. Div. Chem. Soc.* 12:181–184.
- [32] Pravda, M., C. Petit, Y. Michotte, J.-M. Kauffmann, and K. Vytr̃as. 1996. Study of a new solid carbon paste tyrosinase-modified amperometric biosensor for the determination of catecholamines by HPLC. *J. Chromatogr. A* 727:47–54.
- [33] Mirel, S., R. Sandulescu, J.-M. Kauffmann, and L. Roman. 1999. Electrochemical study of some 2-mercapto-5-R-amino-1,3,4-thiadiazole derivatives using solid carbon paste electrode. *J. Pharm. Biomed. Anal.* 18:535–544.
- [34] Rogers, K.R., J.Y. Becker, J. Cembrano, and S.H. Chough. 2001. Viscosity and binder composition effects on tyrosinase-based carbon paste electrode for detection of phenol and catechol. *Talanta* 54:1059–1065.
- [35] Rajendran, V., E. Csoregi, Y. Okamoto, and L. Gorton. 1998. Amperometric peroxide sensor based on horseradish peroxidase and toluidine blue O-acrylamide polymer in carbon paste. *Anal. Chim. Acta* 373:241–251.
- [36] Niranjana, E., R.R. Naik, B.E.K. Swamy, B.S. Sherigara, and H. Jayadevappa. 2007. Studies on adsorption of Triton X-100 at carbon paste and ceresin wax carbon paste electrodes and enhancement effect in dopamine oxidation by cyclic voltammetry. *Int. J. Electrochem. Sci.* 2:923–934.
- [37] Danielson, N.D., J. Wangsa, and M.A. Targove. 1989. Comparison of paraffin oil and poly(chlorotrifluoroethylene) oil carbon paste electrodes in high organic content solvents. *Anal. Chem.* 61:2585–2588.
- [38] Wangsa, J. and N.D. Danielson. 1990. Electrochemical detection for high-performance liquid chromatography using a Kel-F wax-graphite electrode. *J. Chromatogr. A* 514:171–178.
- [39] Wangsa, J. and N.D. Danielson. 1991. Enzymatic determination of ethanol by flow injection analysis using a Kel-F wax carbon paste electrode. *Electroanalysis* 3:625–630.
- [40] Xu, L.-J., N.-Y. He, J.-J. Du, Y. Deng, S. Li, and H.-N. Liu. 2008. Fabrication of porous pseudo-carbon paste electrode as a novel high-sensitive electrochemical biosensor. *Anal. Lett.* 41:2402–2411.
- [41] Xu, L.-J., J.-J. Du, Y. Deng, Z.-Y. Li, C.-X. Xu, and N.-Y. He. 2011. Fabrication and characterization of nanoporous pseudo-carbon paste electrode. *Adv. Sci. Lett.* 4:104–107.
- [42] Xu, L.-J., N.-Y. He, J.-J. Du, Y. Deng, Z.-Y. Li, and T. Wang. 2009. Detailed investigation on the determination of tannic acid by using anodic stripping voltammetry and a porous electrochemical sensor. *Anal. Chim. Acta* 634:49–53.
- [43] Wang, J., U.A. Kirgoz, J.-W. Mo, J.-M. Lu, A.N. Kawde, and A. Muck. 2001. Glassy carbon paste electrodes. *Electrochem. Commun.* 3:203–208.
- [44] Švancara, I., M. Hvizdalová, K. Vytr̃as, K. Kalcher, and R. Novotny. 1996. A microscopic study on carbon paste electrodes. *Electroanalysis* 8:61–65.
- [45] Varma, S. and C.K. Mitra. 2002. Low frequency impedance studies on covalently modified glassy carbon paste. *Electroanalysis* 14:1587–1596.
- [46] Zima, J., J. Barek, and A. Muck. 2005. Monitoring of environmentally and biologically important substances at carbon paste electrodes. *Rev. Chim. (Bucharest)* 55:657–662.
- [47] Nossol, E. and A.J.G. Zarbin. 2008. Carbon paste electrodes made from novel carbonaceous materials: Preparation and electrochemical characterization. *Electrochim. Acta* 54:582–589.
- [48] Miranda Hernandez, A., M.E. Rincon, and I. Gonzalez. 2005. Characterization of carbon-fullerene-silicone oil composite paste electrodes. *Carbon* 43:1961–1967.
- [49] Zhu, L., C. Tian, D. Zhu, and R. Yang. 2008. Ordered mesoporous carbon paste electrodes for electrochemical sensing and biosensing. *Electroanalysis* 20:1128–1134.
- [50] Tang, X.-F., Y. Liu, H.-Q. Hou, and T.-Y. You. 2010. Electrochemical determination of L-tryptophan, L-tyrosine and L-cysteine using electrospun carbon nanofibers modified electrode. *Talanta* 80:2182–2186.
- [51] Liu, Y., L. Zhang, Q.-H. Guo, H.-Q. Hou, and T.-Y. You. 2010. Enzyme-free ethanol sensor based on electrospun nickel nanoparticle-loaded carbon fiber paste electrode. *Anal. Chim. Acta* 663:153–157.
- [52] Chen, L.-Y., Y.-H. Tang, K. Wang, C.-B. Liu, and S.-L. Luo. 2011. Direct electro-deposition of reduced graphene oxide on glassy carbon electrode and its electrochemical application. *Electrochem. Commun.* 13:133–137.
- [53] Wang, L., X.-H., Zhang, H.-Y. Xiong, and S.-F. Wang. 2010. Novel nitromethane biosensor based on biocompatible conductive redox matrix of chitosan/hemoglobin/graphene(room temperature) ionic liquid. *Biosens. Bioelectron.* 26:991–995.
- [54] Yan, Q.-P., F.-Q. Zhao, G.-Z. Li, and B.-Z. Zeng. 2006. Voltammetric determination of uric acid with a glassy carbon electrode coated by paste of multiwalled carbon nanotubes and ionic liquid. *Electroanalysis* 18:1075–1080.
- [55] Thomas JDR (2013) Ion-selective electrode reviews. Amsterdam: Elsevier.
- [56] Morf WE (2012) The principles of ion-selective electrodes and of membrane transport. Amsterdam: Elsevier.
- [57] Abass A.M., Rzajiz J.M., A Review on: Molecularly Imprinting Polymers by Ion Selective Electrodes for Determination Drugs, *Journal of Chemical Reviews*, 2020, 2(3), 148-156.
- [58] Fry C, Langley S (2004) Ion-selective electrodes for biological systems. London:Harwood academic publishers.
- [59] Buck RP, Lindner E (1994) Recommendations for nomenclature of ion-selective electrodes. *Pure App Chem* 66: 2527-2536.
- [60] Thévenot DR, Toth K, Durst RA, Wilson GS (2001) Electrochemical biosensors: recommended definitions and classification. *Biosense Bioelectron* 16: 121-31.
- [61] Salama F.M., Attia K.A., Abouserie A.A., El-Olemy A. Abolmagd E., "Potentiometric determination of Enrofloxacin using PVC and coated graphite sensors", *Global Drugs and Therapeutics*, 3(3): 1-6,2018.
- [62] Abass A.M., (2017). Preparation Pilocarpine hydrochloride, *Journal of Al-Nahrain University*, 20 (4), 13-19.
- [63] Abass A.M., (2017). Synthesis New liquid selective electrodes of ciprofloxacin hydrochloride for determination ciprofloxacin in pure form and pharmaceutical preparations, *Baghdad Science Journal*, 14 (4), 787-792
- [64] Abass AM, Ahmed A. Constraction and potentiometric study of ciprofloxacin selective electrodes. *Int J Res Pharm Chem* 2017;4:425-327.
- [65] Abass AM, Ahmed A. Synthesis and application of trimethoprim selective electrodes. *Res J Life Bioinform Pharm Chem Sci* 2017;3:146-56.
- [66] K. Vytr̃as, I. Švancara, in *Sensing in Electroanalysis*, K. Vytr̃as, K. Kalcher, Eds., University of Pardubice, Pardubice, 2007, Vol. 2, p. 7
- [67] K. Vytr̃as, K. Kalcher, I. Švancara, K. Schachl, E. Khaled, J. Jeřková, J. Konvalina, R. Metelka, *Electrochem. Soc. Proc.* 18 (2001) 277
- [68] K. Kalcher, I. Švancara, R. Metelka, K. Vytr̃as, A. Walcarius, *Heterogeneous Carbon Electrochemical Sensors*, in *Encyclopedia of Sensors*, C. A. Grimes, E. C. Dickey, M. V. Pishko, Eds., American Scientific Publishers, Stevenson Ranch, 2006, Vol. 4, p. 283
- [69] I. Švancara, K. Vytr̃as, K. Kalcher, A. Walcarius, J. Wang, *Electroanalysis* 21 (2009) 7
- [70] R. N. Adams, *Electrochemistry at Solid Electrodes*, Dekker, New York, 1969, p. 280.
- [71] A. Komersová, M. Bartoš, K. Kalcher, K. Vytr̃as, *J. Pharm. Biomed. Anal.* 16 (1998) 1373
- [72] I. Švancara, K. Vytr̃as, *Anal. Chim. Acta* 273 (1993) 195
- [73] K. Vytr̃as, I. Švancara, F. Renger, M. Srey, R. Vaňková, M. Hvizdalová, *Collect. Czech. Chem. Commun.* 58 (1993) 2039.
- [74] K. Vytr̃as, J. Konvalina, *Electroanalysis* 10 (1998) 787.
- [75] K. Schachl, H. Alemu, K. Kalcher, J. Jeřková, I. Švancara, K. Vytr̃as, *Analyst* 122 (1997) 985
- [76] K. Schachl, H. Alemu, K. Kalcher, J. Jeřková, I. Švancara, K. Vytr̃as, *Anal. Lett.* 30(1997) 2655
- [77] K. Schachl, H. Alemu, K. Kalcher, J. Jeřková, I. Švancara, K. Vytr̃as, *Sci. Pap. Univ. Pardubice, Ser. A* 3 (1997) 41
- [78] K. Schachl, H. Alemu, K. Kalcher, H. Moderegger, I. Švancara, K. Vytr̃as, *Fresenius J. Anal. Chem.* 362 (1998) 194
- [79] E. Turkušić, K. Kalcher, K. Schachl, A. Komersová, M. Bartoš, H. Moderegger, I. Švancara, K. Vytr̃as, *Anal. Lett.* 34 (2001) 2633.
- [80] N. W. Beyene, P. Kotzian, K. Schachl, H. Alemu, E. Turkušić, A. Čopra, H. Moderegger, I. Švancara, K. Vytr̃as, K. Kalcher, *Talanta* 64 (2004) 1151
- [81] P. Kotzian, N. W. Beyene, L. F. Llano, H. Moderegger, P. Tuñón-Blanco, K. Kalcher, K. Vytr̃as, *Sci. Pap. Univ. Pardubice, Ser. A* 8 (2002) 93
- [82] T. T. Waryo, S. Begić, E. Turkušić, K. Vytr̃as, K. Kalcher, *Sci. Pap. Univ. Pardubice, Ser. A* 11 (2005) 265
- [83] T. T. Waryo, S. Begić, E. Turkušić, K. Vytr̃as, K. Kalcher, in *Sensing in*

- [84] *Electroanalysis*, K. Vytřas, K. Kalcher, Eds., University of Pardubice, Pardubice, 2005, p. 14
- [85] T. Waryo, P. Kotzian, S. Begić, P. Brázdilová, N. Beyene, P. Baker, B. Kgarebe, E. Turkušić, E. Iwuoha, K. Vytřas, K. Kalcher, *IFMBE Proc.* 23 (2009) 283
- [86] T. Z. Peng, H. P. Li, S. W. Wang, *Analyst* 118 (1993) 1321
- [87] J. H. Pei, Q. Jin, J. Y. Zhong, *Talanta* 38 (1991) 1185
- [88] H. Monien, H. Specker, K. Zinke, *Fresenius Z. Anal. Chem.* 225 (1967) 342
- [89] J. Lindquist, *J. Electroanal. Chem.* 18 (1968) 204
- [90] I. Švancara, R. Metelka and K. Vytřas, *Piston-Driven Carbon Paste Electrode Holders for Electrochemical Measurements*, in *Sensing in Electroanalysis*, K. Vytřas, K. Kalcher, Eds., University of Pardubice, Pardubice, 2005, p. 7
- [91] Schwarz J., Trommer K., Mertig M., "Solid-Contact Ion-Selective Electrodes Based on Graphite Paste for Potentiometric Nitrate and Ammonium Determinations", *American Journal of Analytical Chemistry*, 2018, 9, 591-601.
- [92] R. Metelka, M. Žeravík, K. K. Vytřas, in *Monitorování cizorodých látek v životním prostředí - X*, J. Fischer, J. Kellner, K. Vytřas, Eds., University of Pardubice, Pardubice, 2008, p. 153 (in Czech).
- [93] I. Švancara I., Schachl K., "Testing of Unmodified Carbon Paste Electrodes", *Chem. Listy* 93, 490 - 499 (1999) .
- [94] Ricci F., Conçalves C., Amine A., Gorton L., Palleschi G., a Moscone D., "Electroanalytical Study of Prussian Blue Modified Glassy Carbon Paste Electrodes", *Electroanalysis* 2003, 15, No. 14.
- [95] Liu C., Zhang J., Yifeng E., Yue J., Chen L., Li D., "One-pot synthesis of graphene-chitosan nanocomposite modified carbon paste electrode for selective determination of dopamine", *Electronic Journal of Biotechnology* 17 (2014) 183-188.
- [96] Rajawat D.S., Kumar N., Satsangee S.P., "Trace determination of cadmium in water using anodic stripping voltammetry at a carbon paste electrode modified with coconut shell powder", *Journal of Analytical Science and Technology* 2014, 5:19, <http://www.jast-journal.com/content/5/1/19>.
- [97] Saad N., Jalil M.N., Zain Z.H.M., Zaki H.M., "Effects of Mesoporous Silica Addition on Electrochemical Properties of Carbon Electrode", *International Journal of Engineering and Advanced Technology (IJEAT)*, ISSN: 2249 - 8958, Volume-9 Issue-1, October 2019.
- [98] Maallah R., Smaini M.A., Laghlmi C., Mastour J.E.I., Chtaini A., "Electrochemical Sensor Based on the Clay- Carbon Paste Electrode Modified by Bacteria-Polymer for Elimination of Phenol", *American Journal of Biomedical Science & Research*, 2019.
- [99] Canba E., Türkmen H., Akyilmaz E., "Ionic liquid modified carbon paste electrode and investigation of its electrocatalytic activity to hydrogen peroxide", *Bull. Mater. Sci.*, Vol. 37, No. 3, May 2014, pp. 617-622.
- [100] Mersal, G.A.M., Ibrahim M.M., "Preparation of Modified Electrode *in situ* Carbon Paste Electrode supported by Ni(II) Complex for the Electrochemical Removal of Nitrate from Drinking Water", *Int. J. Electrochem. Sci.*, 6 (2011) 761 - 777.
- [101] Harisha K.V., Swamy B.E.K, Jayadevappa H. , C. C. Vishwanath C.C., "Voltammetric Determination of Folic acid in presence of Dopamine and Ascorbic Acid at Poly (Alanine) Modified Carbon Paste Electrode", *Anal. Bioanal. Electrochem.*, Vol. 7, No. 4, 2015, 454-465.
- [102] Valery H.G., Ngono T.R., Saâdane H., Ennachete M., Khouili M., Abdrrafia Hafid A., Benoît L., Chtaini A., "Evaluation of Carbon Paste Electrodes Modified with Organic Molecules for the Analysis of Heavy Metals by Square Wave Voltammetry", *Valery et al., Pharmaceut Anal Acta* 2013, 4:10,
- [103] Soreta T.R., Gojeh M., Moses Y., Yakubu Y., Bahago N., "Voltammetric And Amperometric Behaviour Of Polyaniline Modified Carbon Paste Electrode For The Analysis Of Atrazine", *IOSR Journal of Applied Chemistry (IOSR-JAC)*, e-ISSN: 2278-5736. Volume 8, Issue 10 Ver. I (Oct. 2015), PP 19-25. www.iosrjournals.org.
- [104] Akbari chermeni S., Krimi H., Keyvanfar M., Alizad K., "Voltammetric Determination of Captopril Using Multiwall Carbon Nanotubes Paste Electrode in the Presence of Isoproterenol as a Mediator", *Iranian Journal of Pharmaceutical Research* (2016), 15 (1): 107-117.
- [105] Belkamssa N., Ouattara L., Kawachi A., Tsujimura M., Isoda H., Chtaini A., Ksibi M., "Electrochemical detection of phenolic estrogenic compounds at clay modified carbon paste electrode", *Journal of Physics: Conference Series* 596 (2015) 012014,
- [106] Silva L.S., Oliveira T.N., Ballin M.A., Peixoto C.R.M., "Ascorbic acid determination using a carbon paste electrode modified with iron(III) ions adsorbed on humic acid", *Ecl. Quim., São Paulo*, 31(4): 39-43, 200
- [107] Pupăzan I.A., Gligor D.M., "Carbon Paste Electrodes Modified with Diatomite adsorbed with Toluidine blue ,used for Nitrite Detection in Water", *STUDIA UBB AMBIENTUM*, LVIII, 1-2, 2013, pp. 111-120.
- [108] Beitollahi H., Tajik S., Asadi M.H., Biparva P., "Application of a modified graphene nanosheet paste electrode for voltammetric determination of methyl dopa in urine and pharmaceutical formulation", *Journal of Analytical Science and Technology* 2014, 5:29.
- [109] El-Mai H., Espada-Bellido E., Stitou M., García-Vargas M., Galindo-Riño M.D., "Determination of ultra-trace amounts of silver in water by differential pulse anodic stripping voltammetry using a new modified carbon paste electrode", *Talanta* 151(2016)14-22.
- [110] Chourak R., Elouahli A., Hatim Z., Chtaini A., Kheribech A., "Electro Analytical Determination of Lead using Tricalcium Phosphate Apatite Modified Carbon Paste Electrode", *Research & Reviews in Electrochemistry*, Vol.6 Issue. 3.
- [111] Khodari M., Rabie E.M., Shamroukh A.A., "Carbon Paste Electrode Modified by Multiwalled Carbon Nanotube "for Electrochemical Determination" of Vitamin C", *International Journal of Biochemistry and Biophysics* 6(2): 58-69, 2018,
- [112] Issa Y.M., Ibrahim H., Shehab O.R., "New copper(II)-selective chemically modified carbon paste electrode based on etioporphyrin I dihydrobromide.", *Journal of Electroanalytical Chemistry* xxx (2011) xxx
- [113] Raril C., Manjunatha J.G., "Voltammetric Determination of Anthrone Using Cetyl Trimethyl Ammonium Bromide Surfactant Modified Carbon Paste Electrode", *Biomed J Sci & Tech Res.*, 2018.
- [114] Mazaheri Gh. Fazilati M., Rezaei-zarchi S., Negahdary M., Kalantar-Dehnavy A., Hadi M.R., "Direct Electron Transfer of Hemoglobin on Cadmium Oxide Nanoparticles Modified Carbon Paste Electrode", *Electronic Journal of Biology*, 2012, Vol. 8(1): 1-6.
- [115] Darmokoesoemo H, Widayanti N., Khasanah M., Kusuma H.S., "Analysis of Uric acid using Carbon Paste Electrodes Modified by Molecularly Imprinting Polymer as Potentiometry Sensor", *Rasayan J. Chem.*, 10(1), 54-58(2017)
- [116] Sedaghat M., Norouzi P., Shamsi J., "Europium Oxide Nanocomposite Carbon Paste Electrode for Determination of Tyrosine Using FFT Continuous Cyclic Voltammetry in a Flow Injection System", *Anal. Bioanal. Electrochem.*, Vol. 6, No. 1, 2014, 43 - 53.
- [117] Tiwari D., Jamsheera A., Zirliannugra , Lee S.M., "Use of hybrid materials in the trace determination of As(V) from aqueous solutions: An electrochemical study", *Environ. Eng. Res.* 2017; 22(2): 186-192.
- [118] Ismail N.S., "Ion Selective Carbon Paste Electrode for Determination of Flavoxate Muscle Relaxant Drug in Pharmaceutical Formulation", *Iranian Journal of Pharmaceutical Sciences*, 2016: 12 (1): 45-58.
- [119] Bolger F.B., Mchugh S.B., Bennett R., Li J., Ishiwari K., Francois J., Conway M.W., Gilmour G., Bannerman D.M., Fillenz M., Trickebare M., Lowry J.P., "Characterization of Carbon Paste Electrodes for real time-amperometric monitoring of brain tissue Oxygen" *Journal of Neuroscience Methods* 195(2011)135-142.
- [120] Ashrafi A.M., Richtera L., "Preparation and Characterization of Carbon Paste Electrode Bulk-Modified with Multiwalled Carbon Nanotubes and Its Application in a Sensitive Assay of Antihyperlipidemic Simvastatin in Biological Samples", *Molecules* 2019, 24, 2215;
- [121] Ait sidi mou A., Datché T., Ouarzane A., El Rhazi M., "Study of carbon paste electrode modified with takawt plant for determination of Cu (II) by differential pulse voltammetry", *J. Mater. Environ. Sci.* 4 (4) (2013) 460-465.
- [122] Aglan R.F., Mohamed G.G., Mohamed H.A., "Chemically Modified Carbon Paste Electrode for Determination of Cesium Ion by Potentiometric Method", *American Journal of Analytical Chemistry*, 2012, 3, 576-586.

Cite this article as: Ali I. Khaleel, Omar Salih Hassan, Role of analytical chemistry techniques in carbon paste electrodes: A review, *International Journal of Research in Engineering and Innovation* Vol-4, Issue-5 (2020), 244-252.
<https://doi.org/10.36037/IJREI.2020.4503>.