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**CONTEMPORARY TRENDS IN ANALYTICAL  
ELECTROCHEMISTRY.  
ASSESSMENT AND PROSPECTS**

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*The aim of this article is to give, after a brief assessment of electroanalytical methods, an outlook on their future applications not only in usual or trivial chemical analysis but mainly in biosciences having the highest priority for us and the whole nature.*

**Role of Electroanalytical Methods**

Electroanalytical methods still play an important role in analytical chemistry in spite of the immense offer of highly sophisticated spectral and chromatographic methods. It is true—and in accordance with various marketing overviews—that electroanalytical methods only represent less than 10% of all the methods used in practice, and within that value the prevailing position is occupied by the electrochemical pH measurements. Thus it seems that for the other numerous electroanalytical methods there is only a limited space or application field. But this is only at the first rather unqualified sight. When evaluating the electroanalytical methods, we have to divide them into already classical methods

like potentiometry, coulometry, conductometry, electrocapillary measurements—to mention only some more important ones—which are mentioned in each textbook on analytical chemistry.

But there is also another group of methods which can be considered to become classical within a short time, or they have already found their position among analytical methods. Without doubt polarography in the mode discovered by Jaroslav Heyrovský must be included. From the point of view of day-to-day applications it seems that this last mentioned method is now concentrated into the “stripping methods”, or anodic or adsorptive ones, which represent a simple and very sensitive methods for trace analysis. On the other hand, “cyclic voltammetry” becomes more and more important in elucidation of electrode processes and reaction mechanisms and serves as a modeling tool for electrosynthesis.

In connection with polarography let us add a few remarks to the just mentioned “Adsorptive stripping voltammetry”—AdSV—(and also stripping potentiometry): Since the early fifties we have been interested (in The Heyrovský Polarographic Institute) in studies of adsorptive and capacitive phenomena on mercury electrodes using oscillographic polarography with alternating current (in accordance with the IUPAC nomenclature this method should be called “Derivative cyclic chronopotentiometry”) [1]. Very soon we observed the possibility of accumulation of the studied compound—organic or metallic chelates—on the electrode surface and thus an increase in the signal due to the higher surface concentration. This was only a logical development step to AdSV [2], with now more than 1500 citations (1997) in scientific journals worldwide.

As just mentioned we oriented our studies prevalently on phenomena on mercury electrodes—at the present meeting stress is exclusively given on applications of carbon electrodes (Vyřas and Kalcher, see Refs [3,4] and references therein) representing not only new ways in electroanalytical measurements but also possibilities in development of new types of electroanalytical sensors. These solid state electrodes (carbon, gold, silver, etc) were followed by a big group of electroanalytical modes now currently used: In short, we could mention the broad field of modified electrodes, biosensors and/or ion-sensitive electrodes. Nor should be forgotten the immense field of commercially produced gas sensors. All these sensors/detectors including the Clark cell for oxygen have found, without doubt, their place among *classical* electroanalytical instrumentation with the prospect of their further improvement and development.

Electrochemical methods are often combined with other physicochemical methods, mostly separation techniques [5]. In general, this is the case of electrochemical sensing in flowing liquids, bringing often the advantage of high sensitivity (given by the sensor) with selectivity (e. g. due chromatographic separation) of the system. Also the combination of electrochemical preconcentra-

tion with ICP-AES or ICP-MS becomes obvious [6].

Assessing the present state of electroanalytical methods we can conclude that these can, like many others, answer not only the questions "what" and "how much" but also questions like "how" and "why" e.g. when the course of chemical reactions has to be clarified—and these all in a broad field of applications. An important quality of the basic electroanalytical instrumentation is their simplicity and low cost. But a drawback in some cases is the necessity of higher skill of the personnel, nevertheless as stated by Nürnberg [7] "the increased sophistication in instrumental design should not be used as a substitute for detailed chemical knowledge required to generate meaningful data from the equipment". Nevertheless the "push button" method is still more and more required and popular.

### Quo Vadis Electroanalitica?

It can be assumed that the above-mentioned classical electroanalytical methods shall remain on the repertory of analytical chemistry like it is the case with titrimetric and gravimetric methods. However steady improvement of sensors, measuring instruments and techniques shall continue. The application field shall cover routine analysis like today on the other hand future trends shall be oriented with highest probability to analysis of biological active compounds, to applications in toxicology, and in general to biosensing. In the biosensor branch stress shall or should be given to elucidation of mechanism of sensing of living organisms and in some respect make use of these phenomena (in fact some biosensors based on bacteria and tissues have been designed, cf [8] ). One of such approaches can be seen in the construction of "electronic nose" (doing the "same" as the human nose receptor) formed of an array of amperometric-conducting-polymer sensors, the signals of the array are mathematically evaluated e.g. by the pattern recognition method [9]. Such instruments just available on the market [e. g. Alpha M. O. S., Toulouse, France] are able to distinguish various odors and in some way perform olfactoric analysis in quality control.

Another important field (initiated by Paleček, see Ref. [10] and references therein) is the detection of some hazardous—toxic—compounds on the principle of some kind of DNA damage present as marker in the solution or better immobilized on the electrode surface. Similarly important seems to be the measurement of the formation of adducts of toxic/carcinogenic compounds with DNA. Another approach is the immobilization of short sequences of DNA specific for some viruses, bacteria, tissues, etc. on the electrode surface (mostly carbon electrodes): is in the solution present the complementary sequence of DNA so after hybridization - formation the double helix, a typical electrical signal can be obtained or by voltammetry or potentiometry. Such applications

contributing to medical diagnostics of some diseases (HIV, TBC, etc.) represent one of the most important fields of science [11-13]. For diagnostic purposes in medicine can serve also the electroanalytical measurement based on the reaction of antigen with antibody in immunological analysis: even here polarography/voltammetry plays an important role [14]. A whole special branch is represented by voltammetry with microelectrodes: they can be implanted e. g. into the body or brain of experimental animals to enable pharmacological studies. This area is a subject of intensive studies [15]. Speaking about voltammetric microelectrodes, we can mention the possibility of intercellular detection of histamine produced in mast cells after application of an allergen [16]. On this basis it would be possible to study the allergenic action of some chemicals on isolated cells.

New perspective field has also been found in a special case of gas phase voltammetry using incorporated electrodes into a polymeric substrate which is penetrated by gases from the environment [17]. Thus, such solid phase extraction makes the method independent of measurements only in liquid media. Wide applicability is also offered by "*Abrasive stripping voltammetry*" [18] - based upon a preliminary mechanical transfer of trace amounts of a solid sample onto the surface of an electrode. The analysis of alloys, minerals, mixtures of powdered substances and also organics (like pesticides from the surface of vegetables or fruits) can be mentioned as examples [19]. Such measurement obviates the need to bring the substrate into solution.

In the first paragraph, electrocapillary measurements are also mentioned. This field has been substantially extended through new theoretical and instrumental development performed by Novotný [20] leading to principal new application possibilities in studies of surface active compounds.

This article considered as an introductory review to meeting can not be exhaustive. Many other areas of electroanalysis are on the freeway to successful applications, e.g. voltammetry on the interface of two immiscible solvents having impact on cell membrane studies, electrochemical scanning microscopy, photoelectrochemical methods, etc. Open is also further fundamental research in the sensor area.

An overview on contemporary analytical chemistry and their perspectives in the twenty-first century is given in paper for comparison [21].

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