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Short Communication

Electrochemical Technologies for Drug and Alcohol Detection

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Abstract

Drugs and alcohol have dual roles in society, offering therapeutic value yet causing harm. Detection methods span environmental and biomedical fields, employing electrochemical sensors and aptamer-based technologies. These systems provide sensitive, selective monitoring of analytes, advancing public health efforts through real-time assessment of substance presence in diverse settings.

Keywords: Drug; Electrochemical technologies; Central nervous system

Introduction

The use of plant derived medicines has been around for centuries [1,2], and ever since then, humanity has had a long and complicated history with drugs and alcohol. On the one hand, there are drugs which are extremely beneficial to humanity such as polyenes for anti-fungal treatments [3,4] and plant derived phenolic compounds as antioxidants [5,6], but there are also some which cause great harm to people and wider society such as opioids [7,8]. But to complicate matters further, there are drugs to counteract the drugs (such as methadone, buprenorphine, and naloxone), which can be used to treat opioid overdose or opioid intoxication [9-12]. Thus, it would seem society has categorised drugs as either “good” or “bad” depending on their physiological effects on humans. The “illicit” drugs are typically used recreationally and can damage the Central Nervous System (CNS) which often leads to various health problems [13,14]. However, society’s values can change over time. This is evidenced by the fact that in 1898 “heroin” was a constituent of some cough medicines [15,16].

The same level of apparent ambiguity and selectivity of social acceptability is also true of alcohols. For example, there is “rubbing alcohol” (concentrated propan-2-ol) which is widely available and used as a disinfectant in many clinical settings and households within the UK; but there is also ethanol in most alcoholic beverages, which is one of the main causes of intoxication within people and animals and the subsequent “hangovers” that people experience. Although, it must be mentioned that in many parts of the world (and in many religions), anything containing alcohol is banned entirely (whether propan-2-ol, ethanol or any other hydrocarbon containing the alcohol chemical functional group).

Drug and alcohol detection can be broadly broken down into two categories, in vivo detection within organisms (humans, bacteria etc.) and detection within the environment. Here, we will consider the technologies commonly used for either scenario and briefly discuss their principle working mechanisms and the scientific theories that underpin them.

Drug and alcohol detection in the environment

The detection of drugs and alcohol within the environment often involves having to take samples from numerous different sample sites to get enough reliable data to form an accurate idea of the analyte distribution within the target area and any long-term or short-term trends for the presence of the analytes of interest. There are many different methods of detection to choose from, depending upon factors such as speed, accuracy, and portability. Examples include portable ethanol sensors for breath analysis by the police [17-20], and electrochemical detection of cocaine within wastewater [21,22]. There are also electrochemical methods of detecting various alcohol vapours [23,24]. Such electrochemical sensors have been widely studied for years [25,26], and are so ubiquitous that they merit further explanation within this manuscript.

Drug and alcohol detection in the body

The detection of drugs and alcohol within people has been an area of active research for decades, although Therapeutic Drug Monitoring (TPM) is generally considered unnecessary for many commonly used medications [27]. Examples include therapeutic drug monitoring *via* concentration levels in the blood [28-31] and drug monitoring in urine [32,33]. Electrochemical aptamer based (EAB) sensors have been used for decades to detect a wide range of biological targets [34-37], and are a promising area of research for in situ monitoring within the body [38,39].

Principles of electrochemical sensing

All electrochemical sensors work on the fundamental principle of electrochemical reactions at the Working Electrode (WE) surface to cause the transfer of electrons into or out of the working electrode, which is then registered as a current flowing through the electrical circuit system. This current can provide quantitative data as it is typically proportional to the amount of analyte reacting at the working electrode surface [40,41]. The reactions at the working electrode can be broadly classed as either chemisorption, oxidation, or reduction. In most standard sensor designs, the analyte must physically move from the inlet (or aperture) at one end of the sensor, to the other end where the WE surface is located. This means passing through several different mediums such as a semi-permeable membrane, a liquid electrolyte, and finally interacting with the working electrode surface (Figure 1). Whilst the analyte interaction with the WE surface is typically the focus during electrochemical sensing, other aspects such as the diffusion rate of the analyte through the different mediums, and the physical length of the different sensor layers can be used to give useful analytical data [42,43].

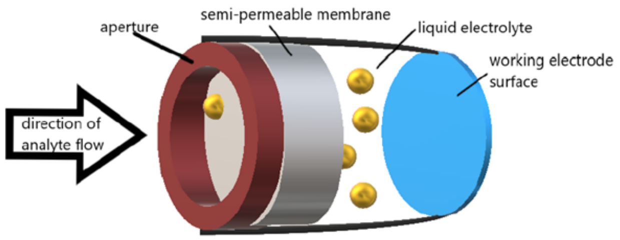

Figure 1: Example analyte travelling through a typical electrochemical sensor.

Electrochemical Aptamer Based Sensors (EABs)

Having already discussed the working mechanisms of electrochemical sensors in general, now we turn our attention specifically to EABs. Aptamers are short, single stranded nucleic acid sequences which are typically derived from either DNA or RNA. They can exhibit high selectivity for binding to the target analyte and can be chemically modified to improve their performance [44,45]. Selection of aptamers is often *via* an in vitro procedure called SELEX (Systematic Evolution of Ligands by Exponential Enrichment) [46-49], which can search through a library of hundreds of different possible options. There are lots of different available aptamers which have been studied in the literature, designed to detect things such as cancer, macular degeneration, and carotid artery disease [50-53]. One of the most common target analytes for EABs is thrombin [54-57] (which is an enzyme involved in the blood clotting cascade by converting fibrinogen into fibrin). Aptamers are typically immobilised *via* thiol functional groups linked to the gold (Au) electrode surface which acts as the WE [58,59]. An example of the thiol binding at the gold Working Electrode (WE) surface is shown for clarity (Figure 2).

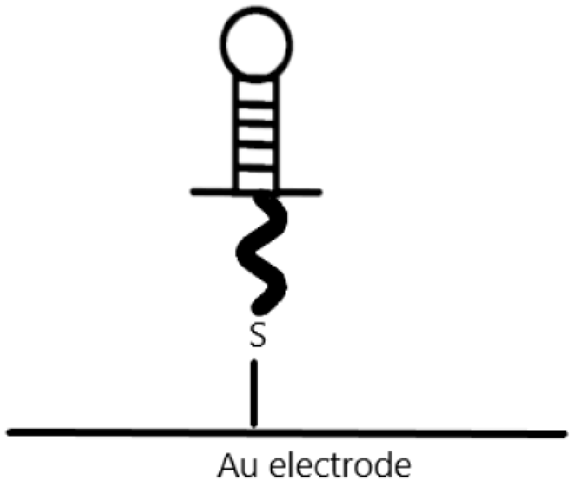

Figure 2: Aptamer binding *via* thiol at the gold Working Electrode (WE) surface.

Conclusion

The principle working methods for electrochemical detection have been briefly discussed, and their use for detection of drugs and alcohol both in the environment and within the body has been shown to be an active area of research. The electrochemical sensor technology for analyte detection is generally well understood and has been covered in depth within the literature previously.

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Data Access Statement

No new data were created during this study.

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