Voltammetric drug testing makes sense at the border

Reference:
Van Echelpoel Robin, De Wael Karolien.- Voltammetric drug testing makes sense at the border
Nature Reviews Chemistry - ISSN 2397-3358 - 8:2(2024), p. 79-81
Full text (Publisher's DOI): https://doi.org/10.1038/S41570-023-00571-1
To cite this reference: https://hdl.handle.net/10067/2026460151162165141

Leave this line which creates the white drop for the title page

Voltammetric drug testing makes sense at the border

Robin Van Echelpoel[1,2] and Karolien De Wael[1,2†]

The European BorderSens project leverages voltammetric sensors, developed with end-users' input, to rapidly and accurately detect illicit drugs. By embracing practicalities and validation, this technology has the potential to combat the illicit drug problem.

The need for new illicit drug sensors

Illicit drugs are harmful substances, posing a threat to the health and safety of society. Each year, over half a million people die as a result of drug overdoses. The violence associated with the illicit drug trade disrupts communities across the globe, there is no region in the inhabited world that is spared from it[1]. Policies, such as supply reduction and harm reduction, are in place to combat the illicit drug problem. Scientists can play a substantial role in this fight by providing tools that enable these policies to be successfully enforced. Crucial are on-site sensors that facilitate identification of illicit drugs in seizures at the point-of-use. Among these, voltammetric sensors stand out as particularly well-suited due to their merits, including cost-effectiveness, rapid analysis, portability, high accuracy, and notably, their orthogonality to existing on-site technologies, such as color tests and portable spectroscopic techniques[2]. However, despite these promising attributes, no commercial voltammetric sensors for illicit drug testing have emerged thus far.

The European BorderSens project was set up in 2019 with the aim of unlocking the potential of voltammetry, enabling it to fulfill the substantial promise it holds in the realm of illicit drug testing. The initiative brings together technology developers (both academic and industrial) with end-users (forensic institutes, customs and police) to ensure that any proposed technology provides both good solutions and fits with the demands of the market. Ultimately the goal is to facilitate the transition of the technology from the confines of the laboratory to practical use (Fig. 1).

Cooperation with end-users

In the past, the solution provided by voltammetric technology proved an inadequate fit for the problem. Colorimetric tests were popular, but their low accuracy was problematic. Although electrochemical tests reached the upper echelons of accuracy, they came with too much added complexity, requiring for example electrode modifications to detect different targets or to provide lower detection limits, ultimately sacrificing other important aspects such as ease-of-use and price[3]. BorderSens actively involved its end-user network consulting law enforcement agencies from 19 different (non)-EU countries, to determine the specifications of a technology solution that truly creates value for the end-user. The result are illicit drug sensors that employ low-cost, unmodified screen-printed electrodes (SPEs), keep analysis time short (< 30 s), but still reach high accuracies (> 95%). Importantly, the voltammetric sensors exploit the orthogonality with current detection techniques, meaning that they are able to identify drugs in samples that are currently problematic for the end-users (such as coloured samples and complex mixtures).

The operation of the BorderSens single sensors consists of the following steps: a few milligrams of sample are dissolved in buffer, and a droplet of the resulting solution is placed on a customized unmodified SPE (Fig. 2). This SPE is inserted in a light, portable potentiostat that is connected wirelessly to a smartphone or tablet. A customized app is installed on this monitoring device to guide the non-expert end-user through the different steps, and additionally, also performs the analysis of the voltammetric signal. The voltammetric signal is obtained by increasing the potential and measuring the resulting current. Oxidation/reduction of analytes creates an increase/decrease in current that can be used for sensing purposes[4,5]. Approximately 30 seconds after starting the measurement, the end-user will see a message on the screen that indicates if the targeted drug is present in the analyzed sample.

Software development

One of the main challenges we faced is making the technology accessible to end-users who are very skilled in their roles, but have little or no experience with science, let alone voltammetry. Interpreting a voltammetric output without experience is almost impossible so we developed a peak-based identification algorithm that does the identification for the end-users[6]. If the detection algorithm is the engine of our software approach, then the graphical user interface is the bodywork – both are essential. We developed a mobile application, once again in consultation with end-users, that guides a user through all the required steps, from sampling to result. We created additional value for the end-user by providing an encrypted report after each measurement, which can be used in prosecution if necessary.

Embracing practicalities

It is only when bringing a technology from laboratory to market, that one encounters practical challenges that are rarely discussed in an academic setting. An interesting example is the sampling procedure: the absence of an analytical balance at the point-of-use, meant that it was challenging to sample a consistent amount. In research settings, we often strive to reach low limits of detection whereas in the border security setting there is usually plenty of sample available. We therefore developed and validated a sampling procedure that employs a smartSpatula — that enables easy and consistent sampling — and a fixed buffer volume to obtain a concentration that accounts for variations in purity of the drug samples, and which provides a consistent concentration range independent of the user.

Additionally, the point-of-use system necessitates consideration of temperature fluctuations that occur as a result of seasonal and geographical changes. To address this, we implemented a temperature sensor within the potentiostat and ensured that the identification software performed temperature-based corrections. Furthermore, we included a diagnostic indicator light to show proper connection of the SPE to the potentiostat. Other considerations in this regard are automated droplet detection, customization of the SPE to indicate the area that should be covered by the buffer, and inclusion of animations in the mobile application to demonstrate the sampling procedure.

Investing ample time in what may seem simple practical concerns is essential, as they hold the power to make or break the success of an application. Our experience has shown that end-users form quick impressions when introduced to a new detection tool. So, ensuring a user-friendly experience and demonstrating a deep understanding of their needs is key in preventing early setbacks.

Validation & demonstration

Bringing the technology from the lab to the field is more than just a catchphrase, it is quite literally what we have been working on for the last several years. First we validated our technology on confiscated samples and later demonstrated the technology to end-users. Analyzing confiscated samples on-site is the best approach to validate the performance of our sensors in real scenarios. Involving the end-users in this validation process, by asking them to select the samples, and performing the validation studies together with them, is an essential part of building trust in a new technology.

Cooperation over competition

The final, although most crucial, hurdle to make true impact with the technology, is commercialization. It isn't necessary to reinvent the wheel to determine the most effective commercialization strategy. On the contrary, it is recommended to apply an established framework such as that described by Gans et al.[7,8] This framework distinguishes four scenarios, based on two factors: the possibility of the innovator to protect the new technology, and the access of the innovator to complementary assets. In doing so, it becomes clear that we fall within the 'ideas factory' category, and that our most optimal commercialization strategy is cooperation with companies already present in the market through licensing deals. In the past we had explored the idea of competing directly with incumbents (launching a spin-off company), but this approach was challenging owing to the niche market for our technology, the fact that we didn't own complementary assets and some specific challenges imposed by doing business with government (widely referred to as B2G). The latter involves tendering procedures, which requires specialized sales channels. We are exploiting our expertise in sensor development to expand our sensor portfolio, and a competitive strategy may become more attractive again in the future.

Robin Van Echelpoel[1,2] and Karolien De Wael[1,2†]

1 Department of Bioscience Engineering, University of Antwerp, Belgium

2 NANOlab Center of Excellence, University of Antwerp, Belgium

†e-mail: karolien.dewael@uantwerpen.be

References

1. United Nations Office on Drugs and Crime. World Drug Report 2023. https://www.unodc.org/unodc/en/data-and-analysis/world-drug-report-2023.html (2023).
2. Florea, A., de Jong, M. & De Wael, K. Electrochemical strategies for the detection of forensic drugs. Curr. Opin. Electrochem. 11, 34–40 (2018).
3. De Rycke, E., Stove, C., Dubruel, P., De Saeger, S. & Beloglazova, N. Recent developments in electrochemical detection of illicit drugs in diverse matrices. Biosens. Bioelectron. 169, 112579 (2020).
4. Compton, R. G. & Banks, C. E. Understanding Voltammetry. (IMPERIAL COLLEGE PRESS, 2010). doi:doi:10.1142/p726.
5. Moro, G. et al. Unlocking the full power of electrochemical fingerprinting for on-site sensing applications. Anal. Bioanal. Chem. 412, 5955–5968 (2020).
6. Van Echelpoel, R., de Jong, M., Daems, D., Van Espen, P. & De Wael, K. Unlocking the full potential of voltammetric data analysis: A novel peak recognition approach for (bio)analytical applications. Talanta 233, 122605 (2021).
7. Gans, J. S. & Stern, S. The product market and the market for "ideas": commercialization strategies for technology entrepreneurs. Res. Policy 32, 333–350 (2003).
8. Teece, D. J. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Res. Policy* **15**, 285–305 (1986).

Acknowledgements

We wish to acknowledge the entire BorderSens consortium. The authors acknowledge the support of the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 833787, BorderSens.

Competing interests

The authors declare no competing interests.

Related links (needs extra line space above)

This is where we could include the link to a video:

CREDIT: A. EDITOR/SPRINGER NATURE LIMITED

Fig 1 | BorderSens development workflow. BorderSens brings voltammetric illicit drug sensors from the confines of the laboratory to practical use by end-users in real scenarios. 1, The technology is co-created by technology developers and end-users to ensure an adequate problem–solution fit. 2, Identification software is integrated in a user-friendly mobile application to make the technology accessible to non-expert end-users. 3, Practicalities are handled to bridge the gap between lab and on-site application. 4, Validation studies are carried out for each target analyte in consultation with the end-users. 5, The final sensors are actively demonstrated at end-user locations in real scenarios. 6, Different strategies are explored to determine the optimal route to commercialization.

Fig 2 | BorderSens single sensor. The BorderSens single sensors require a buffer vial and plastic cap for sampling, a handheld potentiostat and SPE to perform the voltammetric measurement, and a tablet with customized application for data analysis and visualization. The technology is highly portable, which is crucial for an on-site application.