Development of a portable capillary electrophoresis device for forensic field applications

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Background and aim. The need for efficient and portable analytical systems has become a priority in separation science, enabling quick and accurate field-based analyses. Among the available techniques, capillary electrophoresis (CE) stands out as a strong candidate for portable systems due to its minimal reagent use, compact design, and electronically controlled high-voltage separation. This project focuses on the assembling of a compact and portable CE system capable of high analytical performance. The system was tested for the detection of gamma-hydroxybutyric acid (GHB) in urine, a compound often associated with its misuse as a date-rape drug. Analyzing GHB in forensic cases is particularly challenging because it is quickly metabolized (<6 hours in blood, <12 hours in urine), and current commercial on-site methods often lack the necessary sensitivity and specificity [1]. This underscores the need for a more reliable on-field technique.

Experimental section. The separation conditions for the experimental setting were adapted from a previously validated CE protocol for GHB detection [2]. The separation buffer consisted of 20 mM arginine, 10 mM maleic acid, 30 µM cetyltrimethylammonium bromide (CTAB), and 5 mM vancomycin (pH 7.35). The separation was carried out in a fused silica capillary with an inner diameter of 25 µm, and an effective length of 70 cm. Sample injection was pressure-based (0.4 psi for 12.5 seconds), and a capacitively-coupled contactless conductivity detector (320 kHz excitation frequency, 240 Vpp amplitude) was used for the detection.

Results. The compact device was enclosed in a Peli1450® case (dimensions: 37.36 × 25.96 × 15.44 cm), integrating pneumatic and hydraulic components, including a multiport injector with a 10 µL sample loop, two high-voltage power modules, a microcontroller for system control, and rechargeable batteries. The straightforward dilute-and-shoot sample preparation process eliminated the need for complex derivatization or extraction, significantly streamlining analysis. The system exhibited a linear detection range of 15–200 µg/mL, with a detection limit of 5 µg/mL (signal-to-noise ratio = 3) and precision under 6%. Importantly, the device efficiently separated GHB from endogenous compounds like alpha-hydroxybutyric acid (AHB) and beta-hydroxybutyric acid (BHB), achieving a resolution above 1.8. The system’s compact design and high analytical performance make it ideal for deployment in real-world scenarios.

Conclusions. The developed portable CE system offers a groundbreaking solution for on-site analytical needs. Its compact size, minimal reagent consumption, and excellent resolution provide significant advantages for field-based applications. While GHB detection was the primary focus of this study, the system’s flexible design can accommodate a broad spectrum of applications, including environmental testing, food safety checks, and border security inspections. This innovation represents a leap forward in the miniaturization of advanced analytical technologies.

[1] Smits et al. *Therapeutic Drug Monitoring*, 42(2020):139-145.
[2] Gong et al. *Journal of Chromatography A*, 1213(2008):100–104.