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Rapid on-site analysis of e-cigarettes by portable Raman spectroscopy: a tool for law enforcement and drug checking

The use of electronic cigarettes is steadily increasing worldwide, and a growing proportion of devices contain psychoactive substances other than nicotine, such as natural and synthetic cannabinoids [1]. This trend raises public health and forensic concerns, underscoring the need for law enforcement to rapidly distinguish traditional e-liquids (nicotine-based) from non-traditional e-liquids (cannabinoid-based) in the field. Reference methods used in forensic laboratories, such as gas and liquid chromatography, are resource- and time-intensive. A rapid analytical approach allowing direct in-field measurement, without sample preparation or opening the device, is therefore needed. This study evaluates the feasibility of portable Raman spectroscopy combined with machine learning as a rapid, non-destructive approach to determine whether an e-liquid is regulated under Swiss and European legislation or falls outside it, and to provide insight into the type of cannabinoids present. A total of 72 traditional and 130 non-traditional electronic cigarettes and e-liquids, seized in Switzerland, between 2022 and 2025, were analysed by GC-MS and Raman spectroscopy. Across the dataset, at least ten different predominant cannabinoids were identified. Measurements were performed with a handheld MiniRaman spectrometer (LightNovo), with 785 nm laser excitation, whose portability and Bluetooth connectivity to a dedicated smartphone application enable real-time and on-site acquisition of results. Spectra were acquired non-invasively, directly through the vape devices and e-liquid bottles. Four classification algorithms were initially compared. K-NN algorithm showed the best performance, allowing the correct classification of 97% of non-traditional products, with no traditional product misclassified. The second model aims to identify the predominant cannabinoid in non-traditional samples in which it is present in near-pure form, with current efforts focused on the compounds most frequently found in vaping products: Δ^9 -THC, Δ^8 -THC, H4CBD, and HHC. This second model correctly separated the Δ^8 -/ Δ^9 -THC isomers and misclassified only 2 of 58 samples. These results demonstrate that portable Raman spectroscopy combined with ML offers a rapid alternative to conventional methods for the forensic screening of electronic cigarettes. Its handheld format makes it relevant for two complementary front-line settings: police operations, where it could provide a rapid first on-site indication prior to confirmatory laboratory analysis, and drug-checking services, where it could inform users and strengthen harm-reduction and prevention. Future work will focus on testing a wider range of natural and synthetic cannabinoids, expanding the spectral database, and extending the study to an international context.

References

- [1] European Union Drugs Agency, European Drug Report 2026: Trends and Developments (2026), https://www.euda.europa.eu/publications/european-drug-report/2026_en