B105 The Detection of Lead-Free Inorganic and Organic Gunshot Residue (IGSR and OGSR) Using Laser-Induced Breakdown Spectroscopy (LIBS), Electrochemistry, and Machine Learning

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Learning Overview: After attending this presentation, attendees will be able to identify and understand the differences between standard and non-toxic ammunition and the analytical challenges in analyzing GSR.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by describing the characterization and detection of non-leaded GSRs by spectrochemical and electrochemical methods for screening purposes. The combination of both methods improves the accuracy and reliability of IGSR and OGSR analysis.

Current changes in ammunition formulations require the inclusion of emerging GSR methods that could deal with newly manufactured lead-free residues. The current gold standard for GSR analysis is Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM/EDS), which identifiesIGSR elements like lead, barium, and antimony.[1] However, some compositions contain only low atomic number elements that may become more challenging for the automated discovery and identification of GSR particles by SEM/EDS. Therefore, the detection and classification of these elements along with OGSR compounds can complement current practice. Techniques such as LIBS and Electrochemistry (EC) allow for faster identification and simultaneous detection of IGSR and OGSR. In this study, a micro-spot LIBS method was used to collect 25 spectra per stub with simultaneous multielement detection. An electrochemical sensor based on Screen-Printed Carbon Electrodes (SPCE) and square-wave anodic stripping voltammetry allowed for the detection of both IGSR and OGSR data in just a few minutes.

SEM/EDS, LIBS, and EC were used to characterize several non-toxic ammunitions. This presentation evaluates figures of merit such as Limit Of Detection (LOD) and peak resolution for both LIBS and EC methods. Authentic shooter samples were collected using carbon adhesive stubs from the front and back of shooters' hands. A previously collected background population was used for critical threshold comparison with the shooter population. This population set consisted of 100 non-toxic shooter samples and 150 background hand samples. The occurrence of selected elements and organic compounds are reported for the background population as a means to understand prevalence of these residues on the hands of individuals who have not been in the vicinity of a firing event.

In addition to critical threshold values, machine learning algorithms, including logistic regression and neural networks, were used to analyze the performance measures of true positive, true negative, false positive, and false negative rates in comparison to standard ammunition data collected previously by this group. Lower performance than standard ammunitions was seen in the non-toxic population by both LIBS and EC, with an accuracy of 89% and 79%, respectively. Moreover, the orthogonal detection method combining LIBS and EC data resulted in an improved accuracy of 98% on this dataset.

This research study successfully classified the known-shooter samples originating from leaded and lead-free ammunition, providing complementary tools for current methods.

Reference(s):

1. ASTM International. 2017. Standard Practice for Gunshot Residue Analysis by Scanning Electron Microscopy/Energy Dispersive X-Ray Spectrometry. E1588-17. West Conchohocken, PA: *ASTM International*. https://doi.org/10.1520/E1588-17.

Gunshot Residues (GSR), LIBS, Electrochemistry

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