B133 A Chemical Analysis of Gunshot Residues (GSRs) for Investigative Leads and Reconstruction of Firearm-Related Incidents

Courtney H. Vander Pyl, MS, Department of Forensic and Investigative Science, Morgantown, WV 26506; Oriana Ovide, Department of Forensic and Investigative Science, Morgantown, WV 26505; Colby E. Ott, MS, Shippensburg, PA 17257; Luis E. Arroyo, PhD, West Virginia University, Morgantown, WV 26506-6121; Tatiana Trejos, PhD, West Virginia University, Morgantown, WV 26506*

Learning Overview: After attending this presentation, attendees will have learned about the capabilities of Laser-Induced Breakdown Spectroscopy (LIBS) to offer rapid and reliable information in firearm-related investigations and to compliment other confirmatory chemical analyses (Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy [SEM/EDS] and Gas Chromatography/Mass Spectrometry [GC/MS]).

Impact on the Forensic Science Community: This presentation will impact the forensic science community by proposing a practical, objective, and reliable method to modernize the analysis and interpretation of Firearm Discharge Residues (FDRs) in clothing and non-movable objects.

When a shooting incident occurs, materials and compounds originating from the ammunition are deposited on surrounding surfaces in the form of FDRs. These residues, which include Organic and Inorganic GSRs (OGSRs and IGSRs), can become essential pieces of evidence. For instance, when the question of suicide or murder arises, estimating the barrel-to-victim distance may play a critical role in the outcome of a case. Also, clothing, wounds, and other target materials are often inspected to determine an entrance or exit bullet orifice. Conventional methods used in the course of these investigations include colorimetric assays that react with organic compounds and heavy metal components present in the propellant and primer. However, these assays have severe drawbacks regarding reproducibility and selectivity; they are challenging to perform in non-movable objects and are partially destructive of the evidence. Bloody and dark-colored items can significantly diminish the efficacy of these assays. Furthermore, modernized ammunitions (non-toxic) have eliminated the use of the heavy metal compounds needed for some color reactions.

As a result, this study aimed to develop a novel approach that uses LIBS chemical mapping for shooting distance determination on blood-stained clothing, identification of FDR on substrates of interest, and identification of IGSR of standard and non-toxic ammunition. The central hypothesis of this research is that LIBS will provide an enhanced analytical technique for the detection of standard and non-toxic ammunition on target materials because of its ability to simultaneously detect multiple elements in the ultraviolet and infrared regions, in just a few minutes.

The LIBS methods were developed and validated for the analysis of GSRs on substrates commonly found during firearm-related crimes. Residues were analyzed off 133 fabrics, glass, drywall, and wooden samples. For the determination of shooting distance, a calibration curve was created using 15 white clothing samples (100% cotton) covered in human blood, shot at known distances of contact, 6 inches, 12 inches, 24 inches, and 36 inches. An additional ten samples, five pristine white and five samples covered in blood, were shot at unknown distances. Once data was collected, integration of peaks was performed on elements of interest, including antimony (Sb) (259.8nm), lead (Pb) (405.8nm), and barium (Ba) (493.4nm). Principal Component Analysis (PCA) and leave-one-out cross-validated Regularized Discriminant Analysis (RDA) were then performed on the elemental intensities and chemical profiles obtained from these integrations at 20 different locations from the bullet hole. For comparison purposes, the clothing samples were then subjected to conventional colorimetric testing. Color tests resulted in a misclassification of three out of ten shooting distances (30%), while the LIBS method correctly classified the distance range of all unknown testing samples.

For the identification of suspected bullet holes, a total of 21 substrates of different materials (glass, wood, and drywall) were shot from a close distance to simulate the scene of firearm-related crime. The GSR surrounding the bullet hole was transferred to an adhesive sheet to eliminate the need to transfer the substrates back to the laboratory. The adhesive samples were then analyzed by LIBS using a rapid spectral mapping method. Spatial distributions of IGSRs, including Pb and Ba, were used to determine if a bullet created the hole in the substrate. Furthermore, four standard ammunitions (Sellier & Bellot®, Winchester®, Remington®, and TulAmmo®), and four non-toxic ammunitions (Fiocchi®, CCI®, Syntech®, and Inceptor®) were shot into textiles in multiple replicates, then analyzed by LIBS, SEM/EDS, and GC/MS for characterization of their chemical profiles.

Overall, LIBS allowed for rapid and accurate chemical mapping of GSR patterns on pieces of evidence typically found at a crime scene. Chemical imaging of Pb, Ba, and Sb provided more objective approaches to the estimation of shooting distance and bullet hole identification, compared to color tests. Moreover, LIBS, GC/MS, and SEM/EDS provided enhanced detection of standard ammunitions and lead-free ammunition.

LIBS, Inorganic Gunshot Residues (GSR), Crime Scene Reconstruction

*Presenting Author