THE EVOLUTION OF GUNSHOT RESIDUE ANALYSIS AND INTERPRETATION

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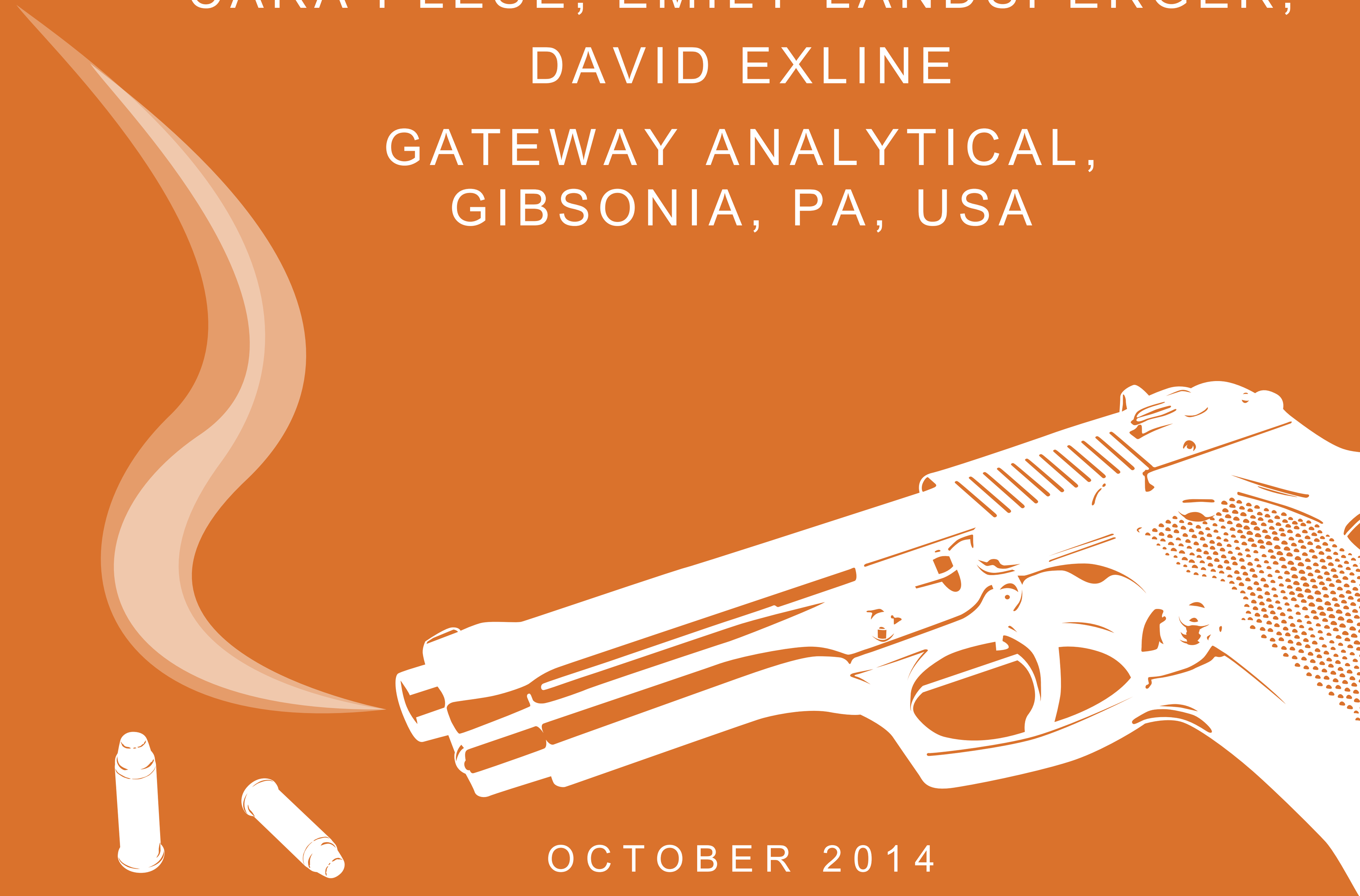

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INTRODUCTION

Gunshot residue (GSR) analysis is a common request in forensic laboratories with cases that question whether or not an individual fired a firearm. When a firearm is fired, several types of residues are expelled from the openings on the firearm. Primer residues, specifically, are detected in GSR analysis. Primer residues are made of particles which contain elements found in the primer of the ammunition used in the firearm. The common Sinoxid-type primers can yield what have been characterized as 'particles characteristic of gunshot residue particles.' Like any combustion reaction, the chemical reaction responsible for firing a gun requires an initiator, fuel for the reaction, and an oxidizer. Sinoxid primers employ lead styphnate as the initiator, or primary explosive, barium nitrate as the oxidizer, and antimony sulfide as the fuel. When a gun is fired, the primer components vaporize due to the extremely high temperatures produced by the combustion reaction and are pushed out of the openings in the gun, due to the force of the reaction. Upon being released into the environment, the vaporized particles combine and re-solidify into single particles, some of them containing a mixture

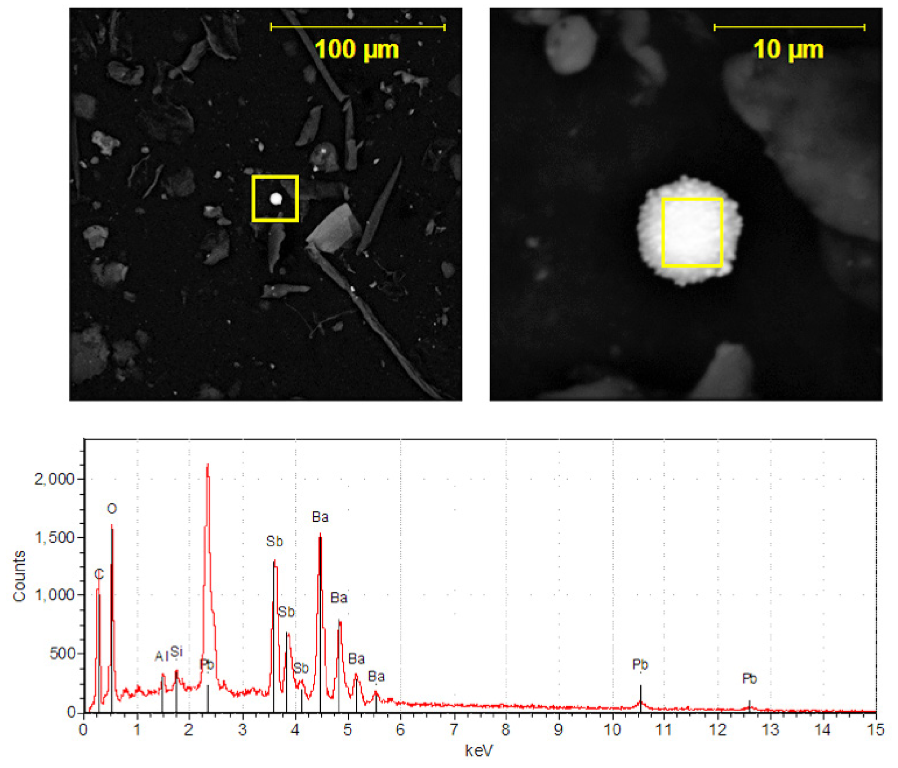

FIGURE 1

SEM-EDS image and spectra of a spherical characteristic GSR particle with visible nodules. The spectrum indicates the presence of lead, barium, and antimony.

of elemental lead, barium, and antimony. Along with the metals from the primer, GSR particles may also contain reminiscent elements from the propellant mixture, metallic residues from the firearm itself, and residual elements from previous firings of the gun. Particles that are molten in appearance, due to formation in high temperatures, which contain lead, barium, and antimony, have been termed particles characteristic of gunshot residue, or 'characteristic particles' [1,2]. Examples of SEM images and EDS spectra of characteristic particles are shown in Figures 1 and 2. Particles of this particular chemical composition and morphology are rarely found in the environment from non-firearm sources [1]. Particles which are molten in morphology and contain two (2) of the three (3) required elements (lead, barium, and antimony) are termed particles consistent with GSR, or 'consistent particles' [1,2]. Single component particles are termed 'commonly associated particles'; particles of this composition are found in the environment frequently from various sources. The presence or absence of particles characteristic of, consistent with, commonly associated with GSR can help substantiate a scenario of whether or not an individual may have fired a firearm.

EARLY METHODS OF ANALYSIS

Early forensic analysis of GSR particles relied on analytical methods which examined a bulk sample (numerous particles together) to determine if lead, barium, or antimony was present. Methods for bulk analysis included Neutron Activation Analysis (NAA), Inductively Coupled Plasma/Mass Spectrometry (ICP/MS), and Atomic Absorption spectroscopy (AA). All of these methods detected and/or measured the presence and concentrations of lead, barium, and antimony collectively in an entire sample. With bulk methods, the sample analysis could not be specific as to the type of GSR particle (i.e. 1, 2 or 3 component). Furthermore, none of the bulk analysis methods allowed for evaluation of the morphology of the samples, which is a critical aspect of evaluating a particle associated with GSR. Due to the specificity associated with characteristic particles which contain lead, barium, and antimony on a single particle, a method of analyzing particles on an individual basis was crucial for reliable GSR testing and interpretation.

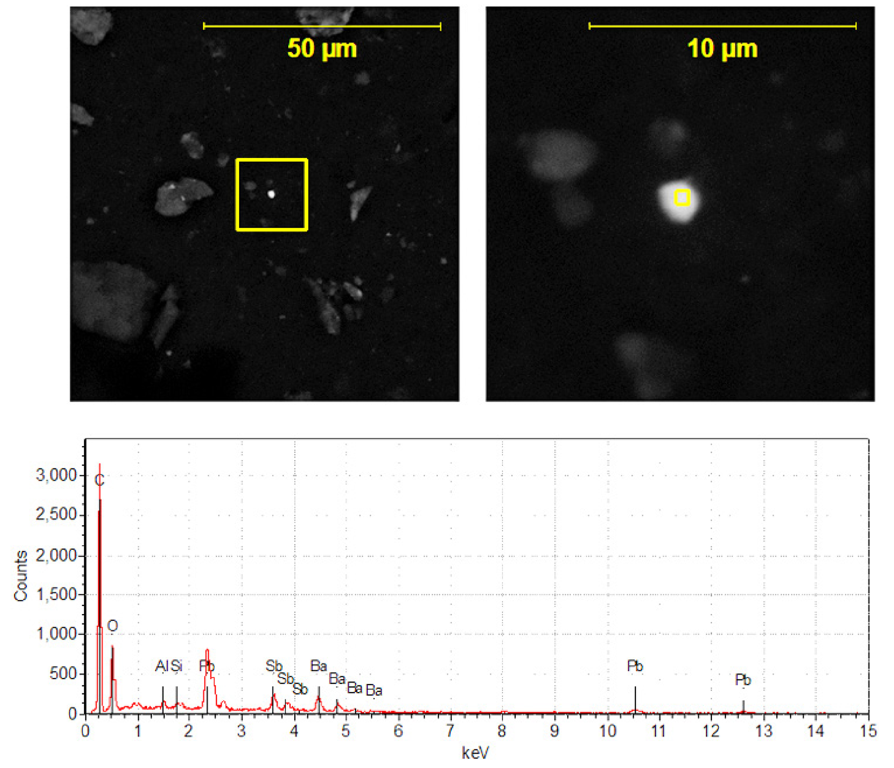

FIGURE 2

SEM-EDS image and spectra of an amorphously-shaped characteristic GSR particle that is approximately 1-2µm in size. The spectrum indicates the presence of lead, barium, and antimony.

CURRENT METHODS OF ANALYSIS

Scanning Electron Microscopy – Energy Dispersive Spectroscopy (SEM-EDS) is currently the most accepted technique for GSR analysis. SEM-EDS technology combines an electron microscope which allows high-resolution imaging of individual particles at high magnification for evaluation of individual particle morphology, with a detector which analyzes the elemental composition of each particle. An example of an SEM-EDS schematic is shown in Figure 3. In 1977, the Aerospace Report was released which deemed automated SEM-EDS analysis as the accepted best method for GSR analysis [3]. SEM-EDS analysis is available in a manually-controlled format; however the process of manually evaluating thousands of individual particles in a sample is extremely time-consuming. Automated SEM-EDS allows the scientist to input parameters and rules for classifying particles and the instrument will methodically categorize particles based on their elemental composition. The automated analysis and categorizing of particles is considered be a presumptive method of GSR particle detection. Following the automated analysis, a trained scientist manually confirms the morphology and elemental composition of particles categorized as being characteristic of, consistent with, and commonly associated with GSR. Automated SEM-EDS is a valuable tool in GSR analysis due to the individual particle analysis and time-saving qualities of the automated features. An example of the GSR data summary provided by SEM-EDS analysis is shown in Table 1.

In addition to technology, terminology regarding GSR particles has also evolved with the further understanding of GSR-like particulate from environmental sources. As other, non-firearm sources of particles containing lead, barium, or antimony were discovered, definitions were altered to take into account the possibility of such particles being introduced by means other than firing a gun. The term 'unique' was once used to describe single particles exhibiting a molten appearance and containing lead, barium, and antimony; however particles falling into this category were also at one time found to be produced by a specific brake pad. It should be noted that lead is no longer used in the manufacture of brake pads due to environmental and health concerns. In addition to

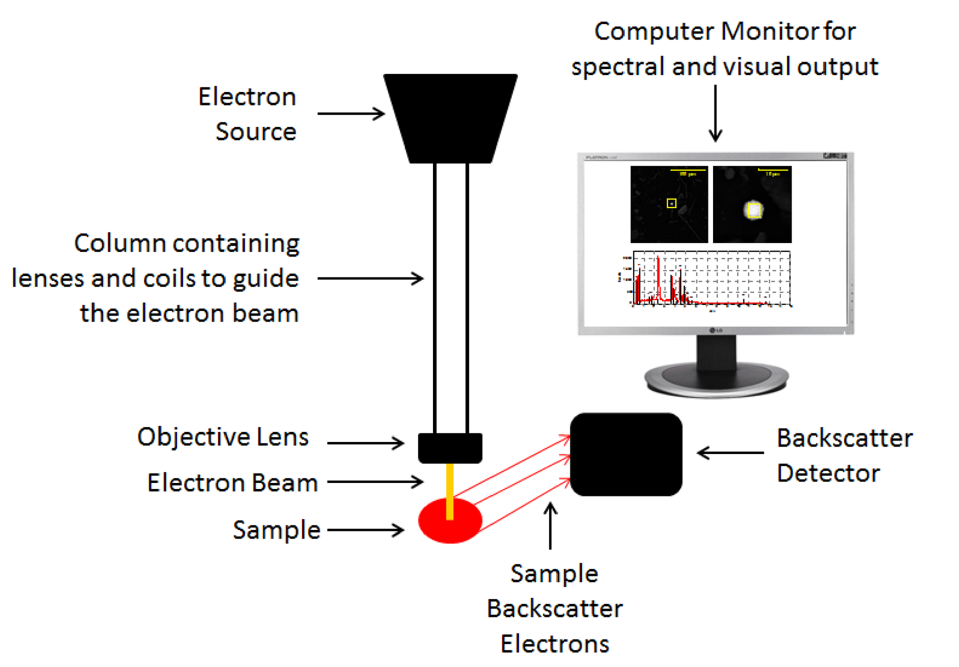

FIGURE 3

Schematic of the inner workings of a SEM-EDS instrument.

brake pads, other sources of particles which could be classified as consistent or commonly associated particles include, but are not limited to: cartridge-operated tools, car air bag deployment devices, fireworks, pigments used in paint, welding materials, and weights used for fishing [1]. Even though particles produced by the aforementioned relatively common objects can contain various combinations of lead, barium, and antimony, particles from some sources can also be eliminated by a trained scientist due to the presence of outstanding elements which are not typically observed in particles originating from firearms, or are typically seen at much lower levels than is produced by some other methods [1].

CONCLUSION

When sampling for GSR, numerous variables can affect how long particles may persist on a surface. Regarding residues on hands of a living subject, normal movements will likely cause the particles to leave the hands in four to six hours, or less. Actions such as washing the hands, sweating, or bleeding can cause the particles to be washed away quickly. If a person wears gloves while firing a gun, the particles may never make it onto his/her hands. Environmental factors when the shooting occurred, such as rain or wind, can also cause particles to be removed from the hands quickly. Another option for sampling for GSR is on clothing. When the GSR particles are released from the gun, due to gravity, they fall on whatever surfaces are in their paths. Particles have been found to remain on clothing longer than on hands [4,5]. If collection of GSR evidence is known to be occurring several hours after an incident, it may be beneficial to collect samples from a suspect's clothing, which may still hold particles even if the particles have been displaced from a suspect's hands.

In contrast to particle loss, it is possible for particles to be transferred to an individual via secondary transfer. If a person comes into contact with a surface which has GSR particles on it, those particles then sometimes can be found on a person even if he/she did not fire a firearm. Due to the possibility of particle loss and particle transfer, the absence or presence of GSR particles alone cannot determine if a person fired a firearm. Since there are several scenarios in which a person may or may not have GSR on their hands, it is accepted practice to report any amount of GSR particles found, even if the number of particles in very small, down to and including, one particle [4]. Other substantiating evidence found at the scene, and also witness accounts and suspect claims, can help investigators and scientists interpret the GSR results.

	# of Particles Initially Located via Automated SEM-EDS	# of Particles Manually Confirmed
Pb-Ba-Sb	57	42
Pb-Ba	25	18
Pb-Sb	48	47
Ba-Sb	36	35
Pb	80	77
Ba	56	48
Sb	45	39

TABLE

An example of the data summary of a typical GSR analysis. The number of particles originally tallied during the automated analysis and the number of particles confirmed via manual confirmation are shown.

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