Gunshot Residue Analysis

Trace evidence is physical evidence that is often difficult to detect by the naked eye, therefore some type of magnification or sensitive analytical techniques are often required to detect or view it. Gunshot residue is one of the most widely utilized and widely examined forms of trace evidence, and it has been utilized successfully in courtrooms across the country for decades.

In the United States alone, 1.3 million people are confronted each year by criminals carrying handguns. Firearms have been used in 40% of robberies, 20% of aggravated assaults, and 68% of all criminal homicides. Because of the number of crimes that involve a firearm, the ability to recognize and properly analyze gun shot residue is an extremely important skill that has helped solve many violent crimes. When a crime involves the discharge of a firearm, the first thing that must be determined by investigators is who fired the gun. When properly obtained and analyzed, gunshot residue can connect the criminal to the proverbial “smoking gun.”

The face of a suspected shooter can also be sampled. This may prove especially useful when a rifle or shotgun has been used in a shooting. Larger amounts of gunshot residue are deposited on the face, chest, and hair when these specific types of weapons are used as they cause significant blowback.

Gunshot residue is preserved longest on articles of clothing, even if a longer period of time has passed from the time of shooting. When a gun is fired, a plume of residue is created that spreads from all openings in the firearm. This cloud then leaves residue deposits on the areas in the immediate vicinity of the discharge. Using adhesive strips or tacky adhesive stubs, forensic analysts frequently examine the objects at a crime scene and take samples from furniture, walls, curtains, carpet or floorings, and other indoor items to help conclude where a shooting took place. Due to the unfortunate common occurrence of drive-by shootings, crime scene experts have also developed methods to collect gunshot residue from the inside and outside of cars involved in these types of crimes.

Gunshot residue should be collected as soon as possible, but particles may remain at a crime scene indefinitely. These particles are extremely durable because they are composed of heavy metals: lead, barium, and antimony. This residue is not readily water-soluble, and, if left to dry in the environment, deposits will not diminish. Such deposits

Following a crime, gunshot residue may be found on the hands, face, or clothing of the suspected shooter, as well as on any object or person in the vicinity of the fired weapon. From both hands, samples should be taken from the front and back of the index finger, thumb, and the web space in between. Residue can also be traced on the hands using a ferrozine, a spray to detect iron.
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can be covered up by dried blood and rough handling, however, thus, collected clothes that might possess gunshot residue deposits must be air dried and packaged in a timely manner to decrease contamination, and clothing should stay on a deceased body until autopsy as to not disturb possible evidence. Evidence should be collected within 6 hours of the crime, but gunshot residue may last longer if undisturbed. The person collecting the evidence should always wear gloves so as to not contaminate evidence from the scene of the crime. Particle sizes range from 1-10 microns and are invisible to the naked eye, so it cannot be assumed that gunshot residue is not present simply because it is not immediately visible.

Gunshot residue is composed of particles of explosive primer, both burnt and unburnt, the propellant, and components of the bullet, cartridge case, and firearm. Explosive primer is a compound that explodes from flame, heat, or shock. When a gun is fired, the firing pin strikes the primer resulting in an ignition that sends a flame into the cartridge case. Gunpowder inside a fired cartridge then burns, changing from a solid to a gas, thus, increasing the pressure inside the cartridge and forcing the bullet down the barrel. The bullet impedes the pressure in the barrel (like a cork in a champagne bottle) until it forces the bullet out of the nozzle, along with residues of gunpowder, in a cone shaped pattern. Gunshot residue particles (which include hundreds of lead, barium, and antimony particles) become airborne, float like ash, and land on nearby objects. After a gun is fired, residue is also easily transferred to surrounding areas by simple contact.

Gunshot residue is often easily identified because it contains both gunpowder residue and lead residue. Gunpowder residue, generally, is composed of black powder residue (made up of a combination of potassium nitrate, charcoal, and sulfur) or smokeless gunpowder residue. Smokeless gunpowder is further classified as single based or double based, where single based powder uses nitrocellulose as its main ingredient while double-based powder contains nitrocellulose and nitroglycerin as its main ingredients. The residue left behind from these powders is present in the form of nitrite compounds that imbed themselves in a target or deposit as a nitrite residue. Lead residues originate from the primer used to ignite the cartridge, and are made up of lead styphnate, barium nitrate, and antimony sulfide. Primer residues are often easier to detect because they do not get as hot as the powder itself, thus, more primer remains after firing. Additionally, lead particulate has greater mass and can travel further distances than the components of gunpowder.

When an examiner finds lead, antimony, and barium combined into a single particle he or she can be sure that the evidence is gunshot residue, as this chemical combination is unique to the compound. The explosion that forces a bullet out of a gun chamber is one of the few ways that these three separate elements can become fused into a single element, therefore when these elements are found in combination with each other, they are classified as characteristic of gunshot residue. In the past, a particle containing only two of these elements could be classified as gunshot residue, however, since 2000, a particle containing all three elements is required to meet the scientific community's threshold for establishing that a substance is gunshot residue.
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In crimes that involve firearm related deaths, gunshot residue has proven to be a valuable tool when examining the body of the victim. During an investigation of this type, examination of the victim's clothing includes a visual and microscopic examination of residue around the bullet hole that includes noting the shape and appearance of the residue pattern, the Modified Griess Test, and the Sodium Rhodizionate Test. The Modified Griess Test is the first chemical test performed because it will not affect later chemical tests. This test detects nitrite residues and is used to determine muzzle-to-garment distance. The clothing specimen with the gunshot residue is placed against a piece of desensitized photographic paper, and the back of the specimen is steam ironed with an acid solution in the iron instead of water. Acidic vapors penetrate the specimen causing a reaction between nitrite residues and chemicals in the photographic paper. The Sodium Rhodizionate Test is used to determine if lead residues are present and is performed by spraying the specimen to be tested with sodium rhodizionate and distilled water. Any lead residue present on the evidence will react with the sodium rhodizionate and turn a bright pink color.

<table>
<thead>
<tr>
<th>Gunshot Residue Technology</th>
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<td>A Scanning Electron Microscope (or SEM) is a type of electron microscope that images the surface of a sample with a high-energy beam of electrons that interact with the atoms making up the composition of the sample surface topography. This technique produces a very high-resolution, three-dimensional image showing details ranging from 1-5 nm in size. Max Knoll performed the first SEM image in 1935, showing electron channeling contrast of silicon steel, and, in 1971, John Boehm was the first person to present SEM images of bullet entrance holes. In 1974, Wessell et al. published a paper on GSR using SEM technology.</td>
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- SEM may be used to detect lead, barium, and antimony in samples and tie them to a single source, namely gunpowder. The SEM is especially good at identifying residue particles because it is capable of detecting the shape, size, and composition of the particles. Many SEMs function in two modes: a secondary electron mode and a back-scattered electron mode. The secondary electron mode produces the highly enhanced three-dimensional images while the back-scattered electron mode is useful for phase differentiation. Additionally, SEM's typically come equipped with an X-ray analyzer and an EDS, which conveys information about the elemental composition of the sample in question.

- Samples for SEM analysis are obtained using adhesive stubs. In gunshot residue analysis, samples are taken from the palm and back of the hand, focusing on the index finger, thumb, and web area in between. The stub is then placed in a vacuum chamber for analysis. Automated SEM analysis, or computer-controlled SEM, is the most efficient technique using SEM technology, as this system screens thousands of particles and stores their composition, size, images, and location in a relatively short period of time depending on the sample being tested. Variable pressure SEM is an alternative method that does not require preparation techniques that might damage or contaminate samples. The SEM generates a magnified image of particles found in clothing and on surfaces while, at the same time, providing an EDS spectrum which breaks down the elements within that particular particle.

- Neutron Activation Analysis (NAA) analyzes the noncombustible portions of gunpowder, namely barium and antimony. A sample is obtained using cotton swabs with a 5% acetic acid solution and bombarded with neutron particles in a process that allows for the identification and quantification of metallic particles that explode onto the shooter's hand during the discharge.

- Atomic Absorption (AA) is similar to NAA, but requires the specimen to be heated. The heating process results in the vaporization of atoms exposed to radiation emitted from a light source. Sensitive recorders then measure and detect the amount of light absorbed by various trace elements, thus, identifying if barium and antimony are present. This method is less expensive and requires less sophisticated equipment than the NAA method.
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Gunshot residue may also be used to determine the distance at which the bullet was fired. Using the suspected ammunition from the case, reference shots are, typically, fired into white denim cloth at varying distances to determine minimum and maximum firing distances. The Modified Griess Test is then performed on the test patterns as described above. Comparing tested residue patterns to that of the actual item of evidence, one can estimate the distance of discharge. Patterns that occur from close range shots will show a more concentrated and tighter configuration of residue compared to distant range shots that will exhibit a sparser and less perceptible arrangement.

Gunshot residue has been used as evidence in many criminal trials. In 2005, actor Robert Blake, star of the 1970’s hit show “Barretta,” was found not guilty for the murder of his wife. One of the defense’s most convincing pieces of evidence was that little to no gunshot residue was found on his person. It was argued, successfully, that the little gunshot residue discovered upon Blake could have resulted from him touching his dead wife or the interior of her car where she was found.

Another case involving gunshot residue involved a man named Tyrone Jones who was found guilty of murdering a 15-year-old girl in 1998, and sentenced to life in prison. During the trial, the jury was convinced of his guilt due to the gunshot residue particles that were found on Jones’ hand. Jones appealed the case, professing his innocence and claiming that the science of gunshot residue analysis is not as confirmatory as the prosecution had led the jury to believe. Jones argued that particles from gunshot residue only “most probably” arise from proximity to a discharging firearm, but that scientists admit that the particles could be spread to a person’s hand by merely touching someone else who has handled a gun. The defense also presented recent studies which reported that gunshot residue transfer may occur by touching a surface inside of a police vehicle. In Jones’ 2010 retrial, prosecutors dropped the charges completely and Jones was released from prison. As Jones was convicted on the presence of gunshot residue only, prosecutors could no longer prove his guilt beyond a reasonable doubt.

The finding of gunshot residue, based on concentrations and location, can certainly implicate an individual that might be involved in a crime involving a firearm, but, at the same time, someone within close proximity of a fired gun might have similar concentrations, patterns, and locations of gunshot residue. Thus, this evidence does not necessarily assign guilt but may be a tool to explaining a guilty action, the events of the crime, and/or placing an individual at the scene of the crime.

Attaining a career that involves gunshot residue testing may include working as a ballistics expert. After obtaining a bachelor’s degree in the fields of criminal justice, forensic science, or criminology, one should apply for internships with local police or a private forensic ballistics agency. One may also continue their education past a bachelor’s degree to earn graduate degrees in forensic sciences. A forensic ballistics expert must possess good reasoning and observation skills, be willing and able to testify in courtroom settings, and be confident in their findings. The reasoning and problem solving skills of this forensic expert, with the help of modern technology, could prove to be the difference in convicting a dangerous criminal.
The Evidence

As investigators collected evidence from the cabin, they found a bullet lodged in the mud outside. They then searched for additional bullets or bullet holes both outside and inside the cabin, but no other bullet evidence was located. When the blue Ford Ranger with the Tumbling Water Land Development Co. logo was discovered in New Mexico, authorities searched the truck for evidence and found an unloaded handgun under a blanket behind the seat.

To determine if the gun had been recently fired, investigators tested several surfaces for the presence of gunshot residue. They swabbed several surfaces inside the truck, as well as the hands of both victims and their clothing.

The evidence was then sent to the laboratory to be tested with both a presumptive test and, if necessary, a confirmatory test utilizing a Scanning Electron Microscope to generate images of the particles and spectra of their elements.
The Mondelos

Louise Ann Mondelo, the 38 year old wife of Lyle Mondelo and mother of Wally and Jan, is also one of the owners of Tumbling Water Land Development Company. Friends say that Louise was in an unhappy marriage and had recently filed for divorce.

Lyle Christopher Mondelo, the 40 year old husband of Louise Mondelo and father of Wally and Jan, is a part owner of Tumbling Water Land Development Company along with his wife.

John Wayne Gretzky

John Wayne Gretzky is 41 years old. He is a friend and business partner of the Mondelo’s in the Tumbling Water Land Development Company. According to rumors, John Wayne and Louise had a brief affair when Lyle and Louise first moved to Highland Park. He is known around town to be a greedy businessman, and has been suspected of shady deals in the past.

An unknown woman of similar height and build has been identified as Louise Mondelo. Although her identity is uncertain, this other woman was found either driving the Mondelo family car with two children preliminarily identified as Wally and Jan, or in a remote fishing cabin with a man who has been preliminarily identified as Louise’s husband Lyle Mondelo.
1. Where are GSR samples obtained from when taken from the hands?

2. Where is GSR preserved the longest?

3. How long can GSR residue remain at a crime scene?

4. What are the components of GSR?

5. What shape does the plume of GSR take as it exits the firearm?

6. What makes up black powder?

7. Where do lead residues originate?

8. What test is the first chemical test performed to determine if GSR is present?

9. What test determines the presence of lead?

10. What is the difference between GSR patterns of close range and more distant ranged shots?

11. What elements are detected when using SEM to detect GSR?
Lab Procedure

Part 1: Gunshot Residue Detection Test

1. Obtain the foam swabs collected from all crime scenes and the positive and negative controls.

2. Starting with the positive control foam swab, place two alcohol swabs on a clean, flat surface, such as the bottom of a Petri dish or a weigh boat.

3. Rub one side of the positive control foam swab onto the first alcohol swab. Flip the foam swab to the other side and repeat the procedure with the second alcohol swab.

4. Place one drop of sodium rhodizinate on the first alcohol swab and observe the reaction. If a red color change is observed, one of the metals specific to gunshot residue has been detected.

5. Place one drop of the diphenylamine solution on the second alcohol swab and observe the reaction immediately. If a blue color change is observed, the test has detected nitrates on the swab.

6. Repeat this testing procedure for the negative control and the evidence foam swabs.

7. Record the results from each swab.

8. When finished with your experiment, formulate a hypothesis as to the events surrounding the crime.

Activity 1: Scanning Electron Microscope

View the video clips to learn about the operation of the Scanning Electron microscope and to look at actual gunshot residue evidence.

Part 2: Examining the Evidence

1. Examine the photos you received from the gunshot residue found at the crime scene. Determine which photos look like residue and measure their size. Describe the particles and explain why they could be gunshot residue.

2. Examine the spectra you received. Identify the three elements that are necessary for the substance to be confirmed as gunshot residue.

3. Measure the peaks for Lead (Pb), Barium (Ba), and Antimony (Sb). Compare the difference in the quantities of each element.
Data Collection and Calculations

Presumptive Test:

<table>
<thead>
<tr>
<th>Swab Number</th>
<th>Victim</th>
<th>Sodium rhodizone (−/−)</th>
<th>Diphenylamine (−/−)</th>
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<tbody>
<tr>
<td>Positive control</td>
<td>N/A</td>
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<td>Negative control</td>
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Data from SEM:

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Contain lead? Quantity? (How many peaks?)</th>
<th>Contain barium? Quantity? (How many peaks?)</th>
<th>Contain antimony? Quantity? (How many peaks?)</th>
<th>Size of particle (diameter in mm)</th>
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Post-Lab Questions

1. Describe the color changes you observed in each test

2. Which swabs tested positive for gunshot residue?

3. Which swabs tested negative for gunshot residue?

4. What does this evidence mean in terms of the crime? What possible scenario could account for the presence of gunshot residue (or lack thereof) on the above surfaces?

5. What three elements are required for a particle to be identified as gunshot residue?

6. Did any of the samples include all three elements?

7. Did any of the spectra contain only two of the elements? If so, which element was missing?

8. Based on the images and the spectra, which particles did your group identify to be gunshot residue?

9. In your opinion, what were the events surrounding the crime?