Paper: Forensic Science & Forensic Medicine
Module: 28, Gun Shot Residue, Determination of range of fire, firearm injuries
### DESCRIPTION OF MODULE

<table>
<thead>
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<th>Name</th>
<th>Affiliation</th>
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<tbody>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Items</th>
<th>Description of Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject Name</td>
<td>Law</td>
</tr>
<tr>
<td>Paper Name</td>
<td>Forensic Science and Forensic Medicine</td>
</tr>
<tr>
<td>Module Name/Title</td>
<td>Gun Shot Residue, Determination of range of fire, firearm injuries</td>
</tr>
<tr>
<td>Module Id</td>
<td>LAW/CJA/VIII /</td>
</tr>
<tr>
<td>Objectives</td>
<td>To understand the role of ballistics in Forensic Science</td>
</tr>
<tr>
<td></td>
<td>To learn about Gun shot residue, its composition, identification, collection and analysis</td>
</tr>
<tr>
<td></td>
<td>To determine the range of fire by which bullet is fired</td>
</tr>
<tr>
<td></td>
<td>To understand the types of injuries inflicted to the body</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Introduction to ballistics, type of powders, their composition.</td>
</tr>
<tr>
<td>Key words</td>
<td>GSR, range of fire, injuries</td>
</tr>
</tbody>
</table>
On pulling the trigger the firing pin of a firearm strikes the primer of a cartridge. The primer compound ignites sending a flame into the cartridge case. Propellant in the cartridge case starts to burn, causing it to change from a solid material to a gas. This change creates a large pressure within the cartridge, which in turn forces the bullet down the barrel and down range. Pressure building behind the bullet decreases as the bullet exits the muzzle of the firearm. When the bullet exits the muzzle, pressure behind it blows the gunshot residues out of the firearm's barrel with high velocity. The residues are expelled from the barrel in a smoky cone shaped pattern. Gunshot residue travels a certain distance after emitting the muzzle of the barrel and leaves a pattern around the entry hole. Gunshot residues can also be emitted from other areas of a firearm. The muzzle-to-garment distance can vary considerably depending on the firearm and type of ammunition being used. Short-barreled firearms and lower velocity cartridges will not normally expel residues as far as a high velocity rifle. At shorter distances however, they may deposit greater concentrations of gunshot residues. Also, gunpowder can come in several forms such as ball, flake, disc, and others. Ball powder being spherical in shape is more aerodynamic than say a particle of flake gunpowder and as a result will travel farther. A number of other variables can influence the amount of gunshot residues that may reach a target; therefore, it is essential that the firearm and ammunition used in the shooting incident be recovered.

**Composition of Gunshot Residue:**

Gunshot residue is normally a combination of gunpowder residues and lead residues. More and more ammunition manufacturers are using lead free or low lead propellants because of the toxicity of lead. Gunpowder residue can contain unburned gunpowder particles, partially burned gunpowder particles or the carbonaceous soot from completely burned gunpowder. Modern smokeless gunpowder, and black powder, contains nitrate compounds. Black powder normally contains a combination of potassium nitrate (75%), charcoal (15%), and sulfur (10%). Smokeless powders can either be single
based or double based. Single based gunpowder will contain nitrocellulose (cellulose hexanitrate) as its main ingredient. Double based gunpowder contains nitrocellulose and nitroglycerin (glyceral trinitrate) as its base. Some triple-based powders are also now available. When either of these types of gunpowder burns the residue left behind will be in the form of a nitrite-based compound. Nitrite particles when emitted from the muzzle of a firearm will strike a nearby target and either be imbedded in the target's surface or leave a deposit of nitrite residue.

Lead residues will be in a vaporous or particulate form and can come from a couple sources within a discharged cartridge. The most common source is the primer. Primers are used to start the ignition process in cartridges and commonly contain lead styphnate, barium nitrate, and antimony sulfide compounds. However, some newer primer compounds are being used that are lead and/or barium free.

Cartridges containing lead based primers, when ignited, produce a vaporous cloud of residue that is expelled from the muzzle of the firearm. Additional vaporous lead residues can be produced when the hot gases pushing a lead bullet down a barrel melt lead from the base of the bullet.

A third form of lead residue will be in a particulate form. Particulate lead residue comes from minute lead particles that are shaved from the sides of a lead bullet as it travels down the barrel. Lead particulate has more mass than vaporous lead and travels greater distances. Also, gunpowder particles can be coated by the vaporous lead residues and leave what appears to be a lead particulate deposit upon striking the target.

The amount of lead residue emitted from a gun can vary slightly from shot to shot. Fouling in the barrel from previous shots can slightly increase the amount of lead residue emitted from one shot to the next.

**Gunshot residue collection:**

When a firearm is shot, in addition to the projectile(s), a mass of debris comes out the muzzle. These gunshot residues (GSR) can include various primer residues, residues from projectiles, and partially burned and unburned gun
powered particles. The examination and analysis of GSR on items of evidence can allow determinations to be made as to whether a hole or defect is consistent with being caused by a bullet (or other firearm-related projectiles).

Additionally, GSR can be transferred to an individual by discharging a firearm, handling a firearm or fired ammunition components, or by contact with another object that has GSR on it. The presence of GSR on a person may provide useful information linking an individual with an action that could transfer this residue to them. As a very general guide, after four to eight hours it is unlikely that residues will be found on a live and mobile individual's hands unless steps have been taken to preserve such evidence (e.g. bagging the hands). The residue can persist for longer periods of time on some areas of interest such as on the deceased, on clothing or other stationary objects. The decision to collect a sample is affected by many variables and must be based on the investigative information available.

Since 1933 several collection and analysis methods relating to GSR have been employed. The most popular method of collection is lifting micro-traces from a substrate upon which GSR has been deposited by multiple pressings of adhesive material until the tackiness of the adhesive has gone. The adhesive material is attached to the head (smooth and flat) surface of a SEM stub as that does not require carbon coating, one that is polished smooth and flat, and does not contain elements of high atomic number.

Both skin and clothing are suitable for the stub method of collection. Specifically, in relation to the hands of the shooter one stub is pressed along the thumb and forefinger and a second along the palm of each hand (resulting in four stubs).

Sticky tape, specialized Micro vacuum cleaners, vacuum lifting onto a filter disc for clothing, plastic shafted, alcohol moistened cotton swabs are other means of collection.

Collection by tape and aluminium stub for use in a SEM is superior to that of liquid adhesives and swabs.
### Particle Type | Elemental Composition(s) | Designation
--- | --- | ---
3 – Component Particle | Pb-Ba-Sb | Characteristic of GSR
2 – Component Particle | Pb-Ba; Pb-Sb; or Ba-Sb | Consistent with GSR
1 – Component Particle | Pb-rich; Ba-rich; or Sb-rich | Commonly associated with GSR

**GSR particle types formed from the discharge of a firearm.**

**Examination of GSR:**

When a firearm is discharged and the bullet strikes a surface, gunshot residues are deposited, particularly at close range. These residues may be reproducible and therefore have evidentiary value. Some residues are visible and others require chemical treatment in order to visualize them.

The preliminary visual and microscopic examinations of gunshot residues should be given first priority because subsequent chemical testing can dislodge residues or alter the appearance of physical effects.

Residues should initially be observed and evaluated by the unaided eye and with a low power (3x-30x) stereomicroscope. Infrared (IR) imaging may be used to visualize heavy soot on dark or bloody clothing.

**Chemical Tests:**

**Modified Griess Test:** The Modified Griess Test is performed first on the exhibit because it will not interfere with later tests for lead residues. The Modified Griess Test is a test to detect the presence of nitrite residues. As described earlier, nitrite residues are a by-product of the combustion of smokeless gunpowder. When a firearm is discharged nitrite particles are expelled from the muzzle of a firearm and can be imbedded in or deposited on the surface of a target. The Modified Griess Test is the primary test used by firearms examiners to determine a muzzle-to-garment distance.

The Modified Griess Test is performed by first treating a piece of desensitized photographic paper with a chemical mixture of sulfanilic acid in distilled water and alpha-naphthol in methanol. Desensitized photographic paper is obtained...
by exposing the paper to a hypo solution. The photographic paper will no longer be light-sensitive but will be reactive to the presence of nitrite residues. The exhibit being processed is placed face down against a piece of treated photographic paper, with the bullet hole centered on the paper. The back of the exhibit being examined is then steam ironed with a dilute acetic acid solution in the iron instead of water. The acetic acid vapors will penetrate the exhibit and a reaction takes place between any nitrite residues on the exhibit and the chemicals contained in the photographic paper. The resulting reaction will appear as orange specks on the piece photographic paper.

**Dithiooxamid Test:**

It is also known as the Rubeanic Acid Test and is a chemically specific chromophoric test for the presence of cuprous (copper-bearing) material. Copper-jacketed bullets represent a considerable percentage of ammunition evidence in criminal cases.

Copper is used in the following types of ammunition:

- Military and sporting jacketed bullets fabricated from gilding metal (a 90/10 copper/zinc alloy) or commercial bronze (a 95/5 copper/tin alloy)
- Rimfire bullets coated or plated with copper or brass (a 70/30 copper/zinc alloy)
- Revolver bullets with copper jackets
- Nickel-plated bullets, e.g. Silvertip bullets

The test identifies a bullet wipe or bullet splash caused by the copper-bearing particulate in the form of bullet jacket fragments found around the perimeter of a bullet hole. While the test is not particularly useful for distance determinations, it can detect residues consistent with the discharge of a firearm or the passage or impact of a copper-jacketed bullet.

The chemistry of the Dithiooxamid Test is comprised of the following process:

- Material from the perimeter of a suspected bullet hole is exposed to an ammonia solution.
- The same material is exposed to a solution of dithiooxamide dissolved in ethanol. If cuprous material is present, a copper complex with a characteristic color forms.
- A dark gray-green color indicates the presence of copper-bearing material in bullet wipe.
- A blue-pink color indicates the presence of nickel (e.g., silver-tipped bullets).

**Sodium Rhodizonate Test:** This chemical test is designed to determine if lead residues are present on the exhibit. The Sodium Rhodizonate Test is performed by spraying the exhibit with a weak solution of a mixture of Sodium Rhodizonate and distilled water. This solution has a dark yellowish/orange color. The exhibit is then sprayed with a buffer solution which causes the background color to disappear.

The Sodium Rhodizionate reacts with any lead that may be present and turns the lead a very bright pink. The pink color is only an indication of the presence of lead residue and to confirm the presence of lead residue the area can be treated with a diluted Hydrochloric Acid solution. If the pink turns to a blue then the presence of lead is confirmed.

**Instruments useful in detection of Gunshot Residue**

The major methods for detection of primer residues are analytical and qualitative. Analytical methods include neutron activation analysis (NAA) as well as atomic absorption spectrophotometry (AAS) and inductively coupled plasma mass spectroscopy (ICP-MS).

Scanning electron microscopy with energy dispersive analysis by x-ray detector (SEM-EDX) and atomic force microscopy (AFM) are used to identify the primer residue qualitatively. An X-ray analyzer can be beamed directly onto the particles visualized with SEM, so that the energy dispersive pattern can be generated, giving the elemental composition of the particles.

For these methods, samples must be obtained from the skin surfaces of a victim at the scene. Delay in obtaining residues, movement, or washing of the body prior to autopsy will diminish or destroy gunshot residues. A rapid loss in numbers of GSR particles occurs from 1 to 3 hours post firearm discharge, though maximum recovery times of 1 to 48 hours have been reported.
Bullet Wounds

Gunshot residues emitted from the muzzle will travel out to distances of approximately 3 and 5 feet in most firearms but in some cases can travel even greater distances. At the 3-5 foot range the gunshot residues may only consist of a few trace particles and make determining the firing distance difficult if not impossible.

As the firearm gets closer to its target the residue concentrations increase and the actual size or diameter to the pattern gets smaller. At around 18-24 inches most firearms will start to deposit considerable concentrations of gunshot residues that may or may not be visible to the eye.

At distances of less than around 12 inches heavy concentrations of visible gunshot residues will normally be deposited.

When the muzzle of the firearm gets next to or is in contact with the target, hot gases escaping from the muzzle at high velocity will typically rip, tear, shred, and/or melt the material of the target. A very intense deposit of gunshot residues will be found around the margins of a contact or near contact entrance hole.

There have actually been cases where a hard contact gunshot (muzzle pressed hard against the victim) caused the residues to blow through the wound tract in the victim and be deposited around the inside of the exit hole of the victim's clothing.

Entry Wounds

The features vary depending on the range from which the weapon is fired—contact, close (intermediate) range or longer (indeterminate) range.

A gunshot wound is a controlled explosion and the bullet is accompanied from the gun by a jet of flame, a cloud of gas, burning and unburnt grains of gunpowder and soot from burnt gunpowder. Entry wounds may show the stigmata of the explosion to a lesser or greater extent.

(A) Contact wound

The muzzle is pressed against the skin. The heat of the discharge causes scorching or charring of the wound. The gases produced by the explosion of the cartridge enter, stretch and split the skin producing a stellate or cruciform tear. The tissue at the margin of the wound may contain soot and powder.
(B) Close range (Intermediate range)

The wound is inflicted at less than arm's length i.e. < 2 - 3 feet. The particles of partly burnt or unburnt powder from the muzzle are driven into the skin around the entrance wound giving a stippled appearance called "powder tattooing" or "powder burns". The area may be blackened by soot. Soot may be wiped off the skin, but powder tattooing cannot be wiped off. The bullet hole may be round or split, the latter being relatively common when there is underlying bone.

(C) Longer (Indeterminate) range

The range is > 2 - 3 feet. The gun is too far from the skin for the products of the explosion to have any effect. Therefore the appearance of the wound is due entirely to the bullet. The wound is usually round (but may be split by "tail-wag" if the gun is fired from the extreme of its effective range causing the bullet to lose its gyroscopic spin and start to tumble).

Marginal abrasion/Abrasion collar/Abrasion ring

The margin of the entry wound in some close range and longer range injuries may be abraded ("marginal abrasion", "abrasion collar" or "abrasion ring") as the bullet inverts the skin and abrades the epidermis as it enters. The shape of this abrasion may help in determining trajectory.

Grease ring

The inner edge of the abrasion collar may be black due to grease or lubricating oil and metal particles from the bullet.

Exit wounds

These show none of the stigmata of the explosion or soiling seen in the entry wound. An exit wound may be the same size as the entry wound, but may be smaller or larger depending on the range, type of weapon, type of bullet, the tissues being traversed by the bullet, etc.

In a contact shot the entry wound is split by the explosive gases and is therefore usually larger than its corresponding exit wound. However, if the bullet comes out carrying bone e.g. a shot to the skull, the exit wound may be larger than the entry.
In a distant shot the exit wound may be the same size or slightly smaller than the entry. In general, exit wounds tend to be split with irregular, everted edges. As a rule, exit wounds DO NOT show an abrasion collar, but exceptionally, this may occur if the skin was pushed up against a hard surface, e.g. concrete wall or floor at the time the bullet exited. This is known as a shored exit wound.

References:

5. http://library.med.utah.edu/WebPath/TUTORIAL/GUNS/GUNGSR.html