# A COMPARATIVE STUDY: DISPERSION PATTERN OF GUN SHOT RESIDUE OF STANDARD AND COUNTRY MADE FIREARMS AT DIFFERENT DISTANCES ON DIFFERENT SUBSTRATE

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**FORENSIC SCIENCE**

BY


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## CANDIDATE'S DECLARATION

I hereby certify that the work presented in the thesis, entitled "**A Comparative study: Dispersion Pattern of Gun Shot Residue of Standard and Country made Firearms at different distances on different Substrate** "in the fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Forensic Science, School of Basic and Applied Sciences, Galgotias University, Greater Noida is an authentic record of my work carried out under the supervision of Prof. (Dr). Arvind Kumar Jain, Dr Prashant Agrawal and Sh. NB Bardhan.

This work has not been submitted in part or full to any other university or institute for the award of any degree.

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This is to certify that above statement made by the candidate is correct to the best of our Knowledge.

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# DEDICATION

Every Challenging work needs self-efforts as well as guidance and blessings of elders especially those who were very close to our heart.

My humble efforts, "I dedicate to the loving memory of my Late. Grandfather".

**"RAO DHANWAT SINGH"**

Who formed part of my vision. The happy memory of my grandfather still provides persistent inspiration for my journey in this life.

I also dedicate my efforts to my Sweet and loving

**"GRANDMOTHER, FATHER & MOTHER"**

Whose affection, love, encouragement, prays of days & night make me able to get such success and honor.

Along with all my hardworking Teachers, family & Friend.

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## Approval Sheet

This Thesis entitled “A Comparative study: Dispersion Pattern of Gun Shot Residue of Standard and Country made Firearms at different distances on different Substrate written by Ms. Komal Yadav for the approval of the award of the degree of Doctor of Philosophy in forensic science.

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# LIST OF PUBLICATIONS

| S.No. | Title | Journal ISSN/Page No. | Scopus/Referred/Peer Reviewed/Other | Name of Journal/Year of Publication |
|---|---|---|---|---|
| 1. | Determination of firing range of firearm by dispersion pattern of GSR | Vol. 6, Issue No. 3, Page No. 9244-9257 | Scopus | Journal of Positive school Psychology,2022 |
| 2. | Pattern of firearm discharge residue on cotton cloth substrate to determine the range of firing by 7.65mm caliber of country made and standard firearm | Vol. 14, Issue No. 4, Page No. 2382-2387 | Scopus | Indian Journal of Forensic Medicine & Toxicology, 2020 |
| 3. | Determination of Range of Firing by GSR-A Review | Vol. 3, Issue No.2, Page No. 22-25 | Peer Reviewed | International Journal of Computational Research and Development (IJCRD),2018 |
| 4. | Dispersion Pattern of GSR of Country made Firearms of different caliber by using SEM/EDX –A Comparative Study | (With ISBN no. 978-81-89128-64-7); Page no. 136 to 144 | Book Chapter No. 17, **Anthropology and Forensic Science: The Current Dynamics** | Publisher: Scientific Selective Books. 2017. |
| 5 | Analysis of gunshot residue of different caliber of country-made and standard firearms on cloth target | Vol. 8, Issue 4, page no. 14 | conferenceseries.com, 6th International Conference on forensic Research and technology held on September 18-19, 2017, Houston, USA | International journal of forensic research, 2017 |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| GSR | Gun Shot Residue |
| CDR | Cartridge Discharge Residue |
| FDR | Firearm Discharge Residue |
| CM | Country Made Firearm |
| KF | Kirkee Factory |
| SEM | Scanning Electron Microscope |
| EDX | Energy Dispersive X-Ray |
| AK-47 | Avtomat Kalashnikova 1947 |

# ABSTRACT

The study on dispersion pattern of Gun Shot Residue has more potential to solve the forensic firearm cases. The dispersion pattern and the elemental composition of Gun Shot Residue plays a very crucial role in the Examination of firearm, estimation of range of fire, identification of bullet holes, identification of shooter, identification of calibre of firearm and identification of type of firearm whether the firearm used in crime was country made or standard firearm. This study was conducted to examine the dispersion pattern of Gun Shot Residue on different substrate by different calibre of country made and standard firearms. In this study, two types of calibre of standard and country made firearms was taken i.e., 7.65mm and .315"/8mm calibre. The ammunition of (khadki factory, Pune) were used for test firing. Two types of Substrates were used for firing test i.e., Paper and cotton cloth. This study needs to test fire from the .315"/8mm & 7.65mm calibre of country made and standard firearms at various close-range distance viz 4", 8" and 12" on cloth and paper target to compare and calculate the dispersion pattern of GSR during the test firing. All test firing were performed in the firing range of ballistics division of CFSL/CBI/New Delhi. After the test firing, The Gun shot residue were carefully examined, Photographed, and collected for further analysis. The Gunshot residue on the target were characterized & analysed into three categories, First by Visual examination, second by Scanning electron microscope and third by using EDX Detector. In the first Step, the determination of firing distance was first observed on the basis of visual examination on the cotton cloth and the paper target at different distance fired by different calibre of standard and country made firearms, the dispersion pattern was somewhat irregular circle. To find out the dispersion pattern area of GSR, we can draw two circles, one near the bullet hole, where more deposition of GSR and another near the outer area, where more tattooing is observed. Now, by putting, the formula of area of circle

i.e., ($A = \pi r^2$) dispersion pattern area of GSR was calculated and then prepare a database, which further help in determining the range of firing and calibre of country made and standard firearm. In the second step, the samples were analysed under Scanning electron microscope to observe the morphology of GSR particles, large variation in the morphology of GSR particles were observed when fired from different calibre of country made and standard firearm on different substrate. In the third step, the samples were run under EDX (Energy Dispersive X-Rays) detector to determine the elemental composition of GSR. Large variations were in the elemental composition of GSR fired from different range, different calibre and different substrate of country made and standard firearms.

This study will be extremely useful for the forensic expert in easy disposal of the cases where range of firing is to ascertain.

# CHAPTER - 1

# INTRODUCTION

# 1. INTRODUCTION

Man has always been fascinated with the ideas of projecting a projectile with the use of weapon on the target. Arrows, stones are the earliest known projectile. This fascination and curiosity lead to the field of Ballistics [1-2]. Ballistics is the field of science which deals with the study of motion of projectile. Forensic Ballistics deals with the examination of firearms range of firearms, Examination of cartridge, cartridge case and Gun Shot Residue [3-4].

## 1.1. FIREARMS

As Per accordance to Arms Act, 1959 **"A firearm is a tool which is used to hurled out a projectile when large amount of gases and pressure are released by the combustion of explosive material"** which includes: -

1. Artillery, Grenade launcher, Pistols, or weapons of various kind, which are made for release of any virulent liquid, gas, or such other things. [5-6]
2. Arrangements for various such firearms are modified to reduce the noise or blast caused by the firing. [1,5]
3. Firearms and cartridges which are assembled by some fragments, equipment, and machines for arranging, transporting and servicing artillery.

Firearms are frequently involved in murders, attempted murders, accidental shootings, suicides, robberies, police firings and police encounters.

Firearms in criminal investigation and trials are assuming an ever - increasing importance. This is mainly due to following factors: -

- Firearms are used in heinous crimes.
- The evidence is accepted in the courts.

- The evidence is permanent.
- The evidence is demonstrative.

Like Fingerprints, Firearm fingerprint is also unique. If a fired bullet is extracted from a dead body or a cartridge case is recovered from the scene of occurrence, the same can be linked to the firearm positively, in over ninety percent cases. [1,5]

Firearms use has been dated back in fourteenth century, but the first firearm was not much of a firearm when compared with the modern systems [1-6]. It was a straight metal tube, closed at one end and open at the other. No projectiles were used at that time.

Later various forms of firearms were invented, and their evolution was as follows [7]:

I. Match lock (1509-1547)
II. Wheel lock (1517)
III. Flint lock (1615)
IV. Percussion-fire (1814)
V. Pin-fire (1851)
VI. Rim-fire (1847)
VII. Centre-fire (1861)

## 1.2. Classification of Firearms

**Firearms can be divided into three main types**:

- Smooth bore firearms
- Rifled bore firearms

- Country-Made Firearms

### 1.2.1. Smooth Bore Firearm

The internal barrel of smooth bore firearms is completely smooth. Smoothbore firearms are designed to fire various pellets/lead balls or sometimes a single projectile. The barrel of shotgun can be measured by the size of bore. Bore is defined as at any point the bore makes a complete circle inside the barrel of shotguns [6,8]. Different bore guns are available i.e., 8, 10, 12, 16 and many bore guns. Shotguns have various diameters. The 12-bore shotgun is the most popular shotgun in India.

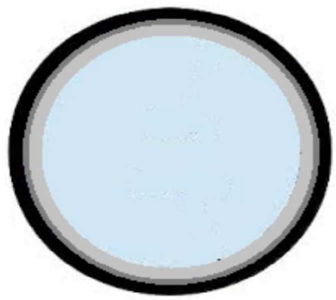


**Fig. 1.1 Internal view of smooth bore firearm barrel**

#### 1.2.1.(a) Types of Smooth bore Firearms

1. Shotgun
2. Swan-off
3. Paradox gun
4. Improvised Shotgun

### Shotgun

The shotgun is an important firearm. The criminals frequently use it in India. The shotgun family of firearms includes almost all smooth bore firearms. [6-11]

**Fig 1.2. Shotgun**

## PARTS OF SHOTGUN

**I) BARREL:**

- A Shotgun is having single barrel or double barrels. These barrels may be attached side by side or they may attach one over another one.
- The single barrel or barrels which is attached side by side are common in India. Shotgun having three barrels are also found but they are not common or rarely found. The third barrel of shotgun is usually rifled, and bullets are fired from it. [6,12]
- The barrels of shotguns are completely smooth bore. Thus, there are 10 bore, 12 bore and 16 bore shotguns.

The barrel of shotgun is having two ends, one is breech end and another one is muzzle end.

- The muzzle end of shotgun carries a sighting pin at the top, which is called the foresight. Another end of shotgun, breech end which is also called the chamber end. It also carries a sighting pin called rear-sight.

**Fig. 1.3 Double barrel shotgun**

## II) BORE

Bore of shotgun is defined as the diameter of the internal barrel which is equal to a spherical lead ball diameter weighing (1/N) of a pound (454 g).[13]

The bore diameter can be found from the given bore number from the following formula:

$$d^3 = 4.6578/N$$

## III) CHOKE

The barrel of Shotgun is often choked. A choke is a constriction which reduces the diameter of the barrel near the muzzle end. The chokes extend inside the barrel to 3 to 15 centimetres from the muzzle end. [13,14]

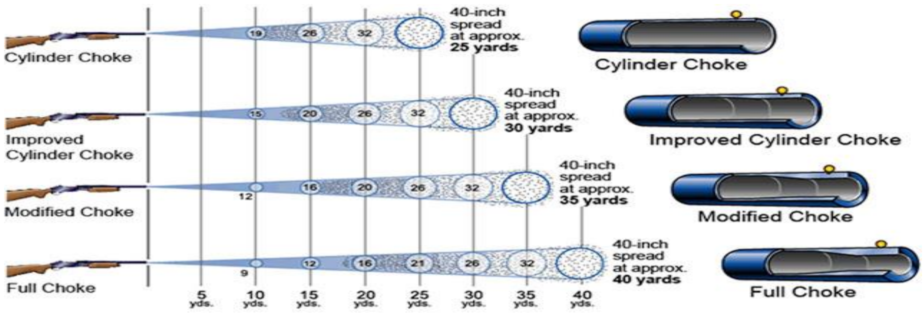



**Fig. 1.4. Types of chokes**

## IV) CHAMBER

Chamber is present near the end of barrel of a shotgun. Chamber is a special cavity to house the cartridge. It is called the chamber. The diameter of the chamber is little bit more than the diameter of the cartridge to be fired from the firearm. This extra space helps in expansion of large amount of gases, created in the firing process [15]. The length of the chamber in a 12-bore shotgun varies from about five to eight centimeters depending to the bore of the barrel through a tapering called the 'CHAMBER CONE'. The length of the chamber cone varies from one to five centimeters. The chamber end carries the extraction and ejection mechanism.

It consists of a claw, which is attached to the rim of the chamber. On breaking open the breech, the claw is pushed out of its base. It brings out the cartridge or the case, which was resting on it. The extraction work is thus completed. The cartridge, or case is picked up and removed from the claw [16].

**Fig. 1.5. <u>Firearm Chamber</u>**

**V) <u>ACTION</u>**

It consists of the mechanism for loading, firing of live cartridge, extraction, and ejection of the fired cartridges. The action includes the magazine and the safety device also. The common actions are pump action and semi-automatic action [17].

**a) <u>PUMP ACTION</u>**

The pump action is also called as trombone action or sliding action. It is very simple in principle. There is a sliding fore-end. When the sliding fore-end is pushed towards the stock or in backward movement, it activates a cam. The cam moves the firing mechanism assembly backward [9,17]. In its backward movement, it extracts and ejects the case which is fired from its chamber and on the return journey, it holds a new cartridge from the rectangular box, loads it in chamber and closes the breech end. Simultaneously, the hammer is cocked, and the firearm is ready for firing.


**Fig. 1.6. Types of action**

**VI)STOCK**

The Stock of shotgun is made up of wooden piece. It is joined to the action block of the firearm. The shape, size and weight have been evolved after a lot of experiments and experience. They are now more or less fixed. The proper construction of the stock has great influence upon aim and comfort in handling the firearms.[18]

**Fig. 1.7. Wooden stock**

## 2) Swan-off shoguns

Swan-off shotgun is having short barrel. It is frequently figure out in crime. The short barrel of swan-off shotgun helps in facilities hiding and portability. They are more popular among criminals.

**Fig. 1.8. Swan-off shotgun**

**3) Improvised Shotguns**

Improvised shotguns (or 12 bore pistols) also have short barrels. The length often varies from ten to forty centimeters.

**Fig. 1.9. Improvised shotgun**

**4) Paradox Gun**

Paradox gun is having two shallow grooves which stamped near the muzzle end. They provide gyratory motion to the single projectiles fired from them. The motion enhances the stability, flattens the trajectory, and maintains the velocity better.

**Fig. 1.10. Paradox gun**

**1.2.2. Rifled Firearms**

Rifled firearms are known by their calibres. Calibre is defined as the distance between two opposite lands. Rifling consists of spiral structure of lands and grooves in the internal (bore) surface of a gun's barrel. A rifled barrel consists of a number of cut and uncut portions. The rifle is just like a shotgun which is having a barrel, an action, and a stock. [6,19]

The number of the grooves in rifled firearms varies from two to sixteen. The number of grooves affects the stability of the bullets. The barrel lengths are usually thirty to seventy centimetres.

**Fig. 1.11. <u>Rifled Firearm</u>**

**<u>PARTS OF RIFLED FIREARMS</u>**

1) **<u>BARREL</u>**

The barrel of rifled firearms contains rifling marks. The number of the grooves in a rifle varies from two to sixteen. The number of grooves affects the stability of the bullets. The barrel length of rifles firearms varies from thirty to seventy centimeters. The uncut/raised portions, which are called **lands**, and cut/depressed portions, which are called **grooves**, are positioned alternately.[20]

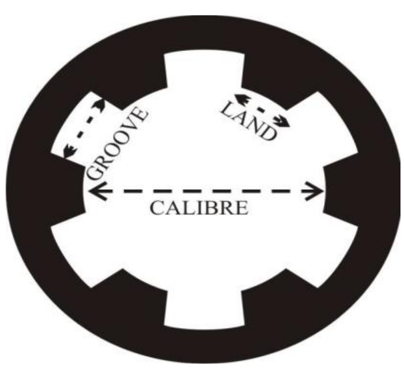



**Fig. 1.12 <u>Internal view of rifled firearm barrel</u>**

A **BROACH CUTTER** is used for the manufacturing of rifling marks (lands and grooves). The spiral structure of the rifling marks is obtained by turning the cutter gradually and uniformly inside the barrel. The broach cutter can be move in clockwise or anti-clockwise direction. The turning inside the barrel is called the **Twist** and the angle of turning is called the **Pitch**. The creation of rifling marks (Lands and grooves) inside the barrel of firearms was a great step towards the improvement and development of firearms. It increased the range and the accuracy of the firearm.

**Fig. 1.13. Different Type of Broach Cutters**

**2) ACTION**

Different actions: Lever action, bolt action and Semi-automatic actions are used in rifles.

**a) LEVER ACTION**

The lever action mechanism in rifles is fixed below the trigger and acts, in addition, as the trigger guard in the normal position. When the trigger is pushed forward, a rod is pulled backward. It extracts out the fired cartridge case from the chamber and cocks the rifle. At the same time, the carrier block is pushed upward which carries along a live cartridge.[21] When the lever is brought to its normal position, the rod places the live cartridge in the chamber and the carrier block takes its original position. The rifle is ready for fire.


**Fig.1.14. <u>Lever action in rifled firearm</u>**

## b) BOLT ACTION

Bolt action is common action in service rifles. The Loading and unloading operations are carried out through a strong steel bolt with a knob. When push the bolt in the forward normal position, the bolt is locked with its knob turned to one side. In this position it seals the chamber. The firearm is cocked in this position.  When the bolt is push backward, the fired cartridge case is also extracted from the chamber and along with the bolt.  Again, when the bolt is pushed forward, it picks up a new live cartridge from the magazine and fix it in the chamber of the firearm. Turning the bolt knob to one side seals the chamber along with the cartridge and the firearm is ready for firing.

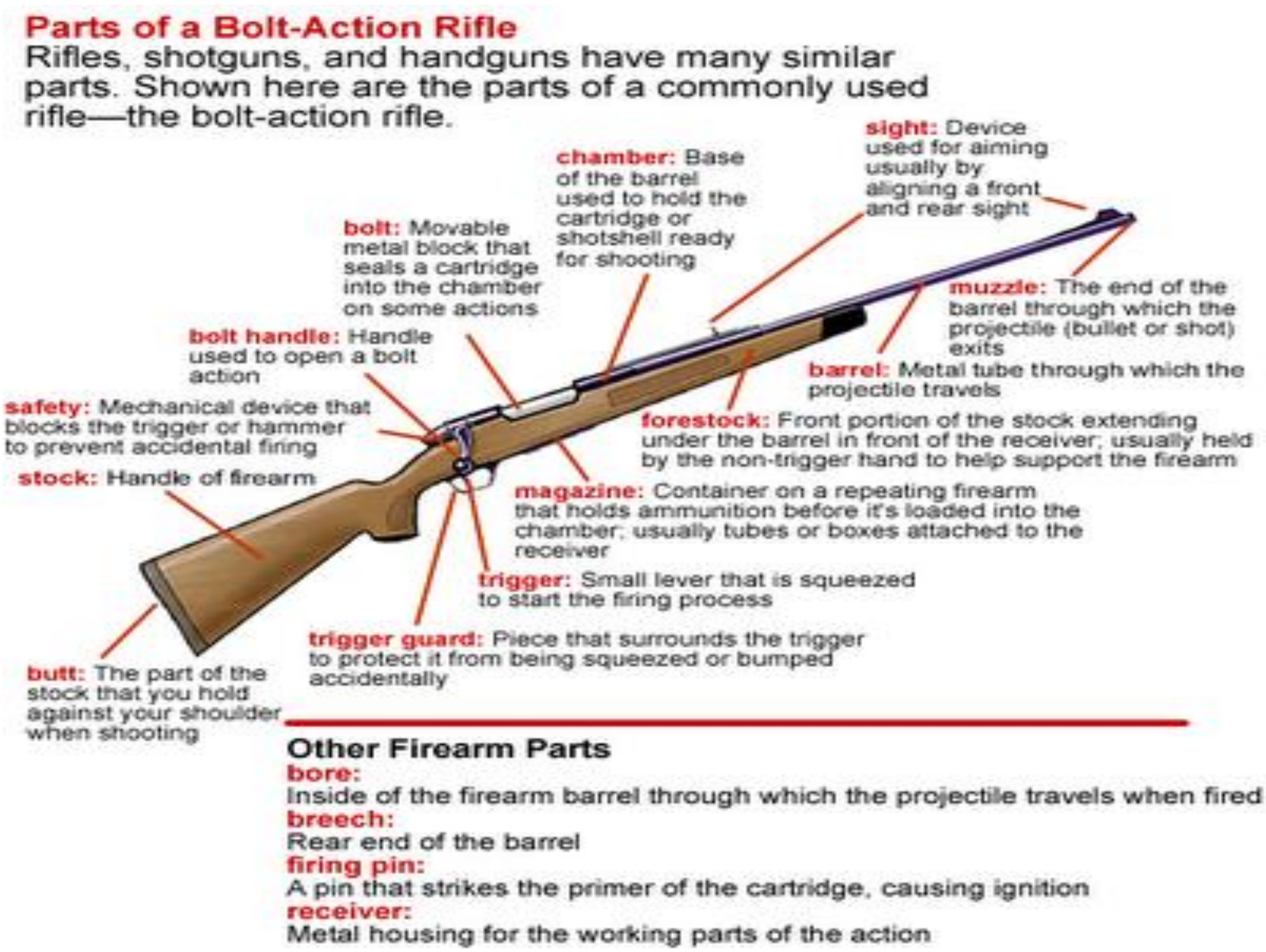



**Fig. 1.15. Bolt action in rifled firearm**

### c) SEMI-AUTOMATIC ACTION

The semi-automatic action is the favourite action of service rifles. In the semi-automatic action, when the firearm is loaded, and cocked, it fires the cartridge, just after pressing the trigger. Simultaneously, the energy of the fired cartridge case is utilized to extract and eject the empty case and load a new one from its chamber and the firearm is ready to cock for next round.[22,23] The semi-automatic action is operated either by recoil action produced in the empty cartridge shell through gases and the outgoing projectiles or by utilizing a part of the expanding gases.


**Fig. 1.16. Semiautomatic action in rifled firearm**

### 3) MAGAZINE

Magazine is the house to load the live cartridges. Magazine is often used in repeating automatic and semi-automatic firearms. It is adjusted with the chambers of the barrel on one hand and with the moving bolt or breech block on the other hand. The magazine is permanently fixed in some firearms and in some firearms, it is not permanently fixed, it is detachable. Both arrangements are working on same principle. There is a spring which is attached to the base of the magazine. It fills up the whole box even when the magazine is empty. When the cartridges are loaded inside the magazine, they continuously depress down the spring. [25,26] The greater the number of cartridges, greater is the compressing till the spring can be compressed no more. The maximum number of cartridges, which can be introduced in the magazine, indicates its capacity.


**Fig. 1.17. Magazine**

**4) STOCK**

The Stock of rifled firearms is same as shotgun firearms. Rifled firearm stock is also working like a shotgun stock. Structurally it is an elongated stock combining fore-end and the stock in a single wooden piece. In modern rifles stocks of plastic materials are being adopted. In some rifles even a skeleton steel structure is used in place of a stock.

**Fig. 1.18. wooden stock**

**TYPES OF RIFLED BORE FIREARM**

**1) PISTOL**

Pistol is a rifled hand gun firearm, which can be fired by one hand. Pistol has a magazine which is unlocked in its grip. Pistols are available in various calibres from about 5 to 12 mm. The barrel of the pistol is having five-six lands and grooves in the left hand direction, and it is known as colt type pistol and if the rifling in the right hand direction is known as smith and Wesson type pistol. Pistols are normally semi-automatic or self-loading type in which the pull of the trigger of a cartridge is final.

**Fig.1.19. Pistol**

## 2) REVOLVER

A Revolver is a rifled handgun which can be fired by one hand. Revolver is having a revolving cylinder having chambers for loading the cartridges. The number of chambers in revolver may vary from 4 to 7. When the trigger of the firearm is pressed, the cylinder rotates and bringing one of the chambers in line with the barrel for firing. Revolver is also available in various calibers. The revolvers have short barrel, and they are effective only at short range. [25,26] There is some space between barrel and the revolver cylinder which is responsible for leakage of gases and powder residues which are deposited on the hand of the shooter which permits the identification of the shooter, and they allow the identification that shooting was done by a particular hand of the individual.

**Fig. 1.20. Revolver**

## 3) MACHINE GUN

The machine gun is a fully automatic rifled firearm. It is designed to fire rifle ammunition. Recoil action and gun operating actions are common in machine gun. Blow back operation is not common in machine gun because of the greater power of the cartridge.[27] In machine gun, the rate of fire is 300 to 1800 shot per minute, which is very rapid, and it depends upon the feeding system.

**Fig.1.21. Machine Gun**

## 4) SUBMACHINE GUN

A submachine gun is just similar to machine gun which is a fully automatic firearm. It is simply a machine gun designed to fire small cartridges like pistol ammunition [27]. Actions which are more common in Sub-machine gun are recoil or gas operated.

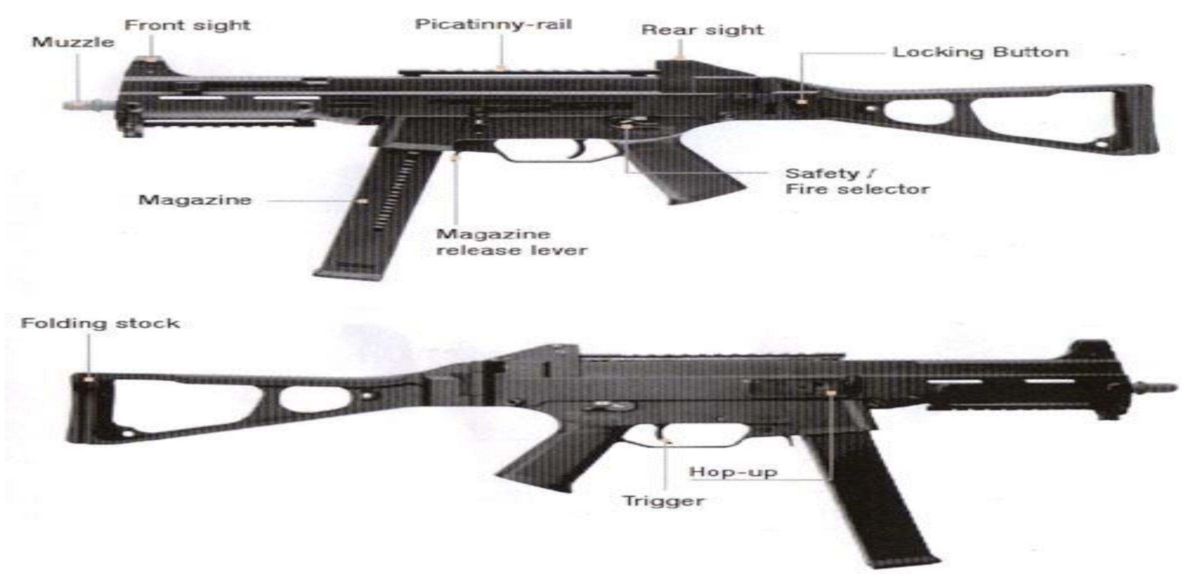



**Fig.1.22. Sub-machine gun**

**5) AK 47**

The AK-47 is also known as Avtomat Kalashnikova and 47 represent the year in which, it was made. It was made in 1947. AK47 is an assault rifle, and it is modified version of service rifles. They are gas operated. AK47 is very common among terrorists in our country and elsewhere. The Russian assault rifles AK 47 (calibre 7.62mm), of Russian design, through manufactured in various modified forms all over the world, are being used extensively by the terrorist.[27]

**Fig. 1.23. AK-47**

### 1.2.3. Country- made Firearms

A large variety of country made firearms are made in different states of the India. A variety of ammunition are also made in different regions of the country. Besides, some of them country made firearms are manufactured to hurled out the standard cartridge of two or more close calibers [28,29]

Country made firearms are also known as Home-made firearms as they are manufactured by local blacksmiths or illegal manufacturers from easily available household materials. These materials may be iron pipes, car steering's pipes, and house pipes, etc. with crude tools for the firing mechanism.

Country made firearms are commonly known as zip guns, desi-*katta*, *addhi*, tamancha etc. Due to the ease and inexpensive availability, these weapons are favorite choice for the criminals.

There is tremendous demand for these weapons in U.P. Bihar, and in some border states. The demand of country made firearms is increasing day by day. Country made Firearms are involved in heinous crimes, provide clinching linking evidence. In India 2014-2017, firearms were used in 12% of murders, 18% of attempted murders and 7% of robbery offences [30]

These firearms are being made in local market without any specifications, nor any standard raw material. Since such firearms are being produced by local hands with less or no experience and without specialized tools therefore these weapons have short span of life.

The country-made firearms are used by culprits as they are readily available in market at cheap prices. Due to their non-standard nature these weapons are usually imperfect and are highly dangerous even to those who use (fire) them.

Even though India is very strict in gun control act, our country comes on second largest civilian firearms in the world. In the year 2011 about 48% of all murders were committed by illegal and unlicensed weapons [31]

Country made firearms are frequently used in the commission of crime, also to frighten the victims in tensed crime situations. In India most of the crimes, are committed using the country made firearms as the legal possession of standard firearm is highly restricted. The percentage of usage of country-made firearms varies from state to state. Thus, these country-made firearms are of great importance in criminal investigation work.


**Fig. 1.24. <u>Country-Made Pistol</u>**

The country-made firearms have the following usual parts:

**I. <u>Barrel:</u>** -

Country-made firearms have non-standard barrel, they are often a hollow cylindrical piece of iron or steel used in sanitary or electrical work or even Steering wheels of heavy-load vehicles. The length of barrel varies from about 10 cm to 25 cm in case of handguns, and it is about 60 cm in the shoulder firearms. The following points are note-worthy about the barrel of such guns: -

1. The diameter of the bore is same as that of a standard firearm. It varies from 1 cm to 2.5 cm usually. It may even vary from one point to other in the same barrel.
2. Internal surface of the barrel is sometimes smooth and sometimes rough.
3. The thickness of barrel varies from one firearm to the other.

4. The barrels are welded from a piece of single sheet to form a complete circle.
5. Rifling is absent in the barrel.
6. The loose, rough, and non-uniform barrels of the firearms are responsible for the varying ballistic performance of the ammunition from one shot to the other.

**II. <u>Chamber</u>**

The country-made firearms do not have specially made chambers. In most of them the barrel end serves as the chamber. The chambers, if they exist, do not have proper dimensions, nor do they have any arrangement for housing the cartridge in proper position. Therefore, the cartridge often rests loosely in the chamber, which is responsible for the improper ballistic of the firearm.

**III. <u>Action</u>**

The hammer, trigger and firing pin are the most important parts of the firearm. The main distinguishing characteristics of the action are:

1. The firing pin strikes the percussion cap which holds primer mixture necessary for combustion of the charge. But due to imperfect dimensions of the firing pin in the country made a firearm, sometimes the firearm backfires which is extremely dangerous.
2. The firing pin of country-made firearms can easily be replaced. Criminals have replaced the firing pin or mutilate its original surface characteristics. The fraud doesn't help much as the breech marks provide necessary identification data. [6-12]

The following points about country-made firearm ballistics may be noted: -

1. These firearms become increasingly dangerous with each subsequent shot due to irregular dimensions.
2. They are effective only at short ranges as the combustion of propellants is often incomplete and extent of combustion varies from shot to shot.
3. They do not permit accurate or even approximate estimates of range from the spread of pellets or direction of wound.
4. The data collected from one firearm cannot be used for a second country-made firearm, even if the ammunition of the same make and batch is used.
5. The marks imprinted on the projectiles or shells fired from country-made firearm are numerous and characteristic, which facilitate the identification of the fired ammunition.

### 1.3 Ammunition

Ammunition is a substance which can be fired, dispersed, or detonate from any kind of weapon.

As Per accordance to Indian Arms Act, 1959, Ammunition means, "Ammunition for any firearm" includes:

i. Grenade launcher, missiles, bombs, Rockets.

ii. Articles which are designed to have explosive material, poisonous liquid, gas or other such material, which are capable of use with firearms or not.

iii. Fuses or friction tubes.

iv. Machinery parts for ammunition manufacturing

Mostly crime committed can be done with the help of small arm ammunition, which consists of cartridge, primer, propellent, projectile and wads.

Small arm ammunition can be of two types:

1. Rifle cartridge
2. Shotgun cartridge

Rifle cartridge is consisting of metallic cartridge case, percussion cap which contain primer, Propellant (Gun powder) and bullet.

**Fig. 1.25. <u>Different types of Rifle Cartridges</u>**

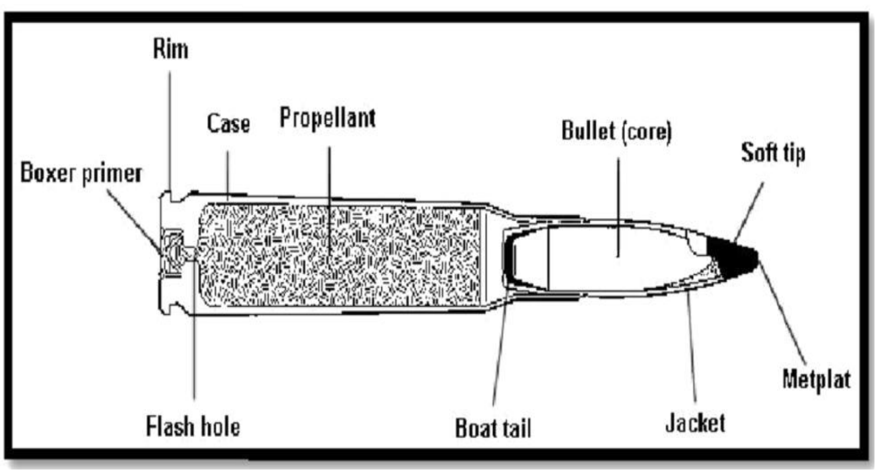



**Fig.1.26. <u>Parts of Rifle cartridge</u>**

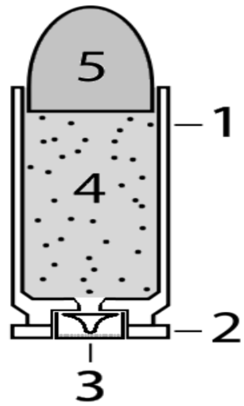



**Fig.1.27. <u>Parts of ammunition</u>**

**1.3.1. <u>Cartridge Case</u>**

The cartridge case is like a metallic container, which is shown on number 1 in the figure 1.26 and it is made up of the brass metal. It holds the percussion cap, primer, projectile together in the case. The cartridge case prevents the escape of gases during discharge of firearm.

**1.3.2. <u>Percussion Cap</u>**

The percussion cap is a metallic cap, which is shown on number 3 in the figure 1.26. The Percussion cap is also known as Primer cap. It contains small amount of explosive powder, which is exploded by striking the firing pin on the base of percussion cap.

**1.3.3. <u>Primer</u>**

The Primer, shown on number 3 in Figure 1.26. The composition of primer releases amore amount of particles and hot gases. Primer compositions is consisting of mixture of compounds. A primer composition consists of:

- An initiator

- Fuel
- Oxidiser
- Stabiliser

**Table 1.1. <u>Showing the Latest composition of Primer mixture used in India are</u>:**

| Component | Percentage % |
|---|---|
| Lead Styphnate | 32-42% |
| Antimony Sulphide | 13-17% |
| Barium Nitrate | 27-37% |
| PETN | 4-6% |
| Tetracene | 3-5% |
| Aluminium | 6-8% |

Initially, the primer composition mixture was placed in paper strips and fed over to the flash hole of a cartridge where it was struck by firing pin and give out flame& ignite the powder charge. Paper pellet primers were later replaced with metallic cup, which are known as percussion caps. The percussion cap is manufactured by sheet of copper, brass, cupro-nickel alloy, or gilding metal of appropriate thickness.

The primer mixture is highly sensitive to heat, pressure, impact, and friction.

### 1.3.4. Propellant

The propellant, shown on number 4 in the figure 1.26. The propellant is a chemical substance, which hurled out the projectile from the firearm due to expansion of large amount of gases. Three types of propellant are used:

1. Black powder
2. Smokeless Powder
3. Semi-smokeless Powder

**1.** **Black Powder**: Black Powder was the first propellant to be used in firearms. Black powder is also known as Gun Powder. Black powder is not used for high velocity firearms due to its hazardous nature and its inability to provide high speed Black powder was replaced with smokeless and semi- smokeless powders. These powders provide proper ballistic to the projectile with high speed. Therefore, in modern ammunition smokeless and semi-smokeless powders are being used.

**Table 1.2. Showing Composition of Black Powder are:**

| **Component** | **Percentage %** |
|---|---|
| Potassium Nitrate ($KNO_3$) | 75% |
| Charcoal | 15% |
| Sulphur | 10% |

2. **<u>Smokeless Powder</u>:** Smokeless powders are used in high velocity firearms. Basic component of smokeless powders are nitroglycerine and nitrocellulose. Nitrocellulose is also known as Gun cotton. Nitrocellulose can be used alone, or it can be used in combination with nitroglycerine. When nitrocellulose is used alone, it is known as single base powder. When nitrocellulose is used with the combination of nitroglycerine, then it is known as Double base powder. Smokeless powder is degraded with time. Their life span can be increased by the addition of stabilizer.[32]

3. **<u>Semi-Smokeless Powder</u>:** Semi-smokeless powder consists of black powder and nitrocellulose. The composition of semi-smokeless powder is: -

   Nitrocellulose - 20%

   Potassium Nitrate - 60%

   Sulphur - 8%

   Charcoal - 12%

   Semi-smokeless powder produces less smoke than black powder. The mixing process of these ingredients is extremely dangerous.

### 1.3.5. <u>Projectiles</u>

The Projectiles, denoted in figure 1.26. By the number 5, is anything which propels out of the firearm. Projectile can be pellets; buck shots, balls, bullets, etc. intended to cause injuries. They are hurled out of the barrel, when large amount of gases produced by the propellants on the discharge of a firearm. The projectiles used in firearms have undergone the usual evolution from stone to modern day bullets.

The first projectile which is fired from a rifled firearm was made of lead but due to low melting point and high specific gravity, and the use of smokeless powder, the lead bullet gets deformed as it generates higher velocities and higher temperature. Due to this drawback of lead bullets, development of jacketed bullets takes place. In jacketed bullet, covering of copper jacket can be done on the upper surface of lead bullet. The Jacket of the bullets is made up of copper. There are various shapes and sizes of bullets which made them useful for specific kinds of firearms depending on the caliber of firearm.

**2. Shotgun cartridge**

Shotgun cartridge consists of Plastic or cardboard cartridge shell, Percussion cap or primer cap, Propellant, Projectile (Spherical lead balls or pellets) and wads (overshot wads, undershot wads, Air-cushion wads, and base wads.

1. **Cartridge case**- The cartridge is home for primer, propellant, wads, and projectile. It holds all the material together inside the case. It is usually made up of plastic and crimped at the end. Crimping plays an important role in helping to manage the pressure within the cartridge.
2. **Percussion Cap-**The percussion cap is a metallic cap. The Percussion cap is also known as Primer cap. It contains small amount of explosive powder, which is exploded by striking the firing pin on the base of percussion cap.
3. **Primer-** The composition of primer releases a more amount of particles and hot gases and particles. A primer composition consists of:
   - An initiator
   - Fuel
   - Oxidiser
   - Stabiliser

The Latest composition of Primer mixture used in India are lead styphnate (32-42%), Antimony Sulphide (13-17%), Barium Nitrate (27-37%), PETN (4-6%), Tetracene (3-5%), Aluminium (6-8%).

Initially, the primer composition mixture was placed in paper strips and fed over to the flash hole of a cartridge where it was struck by firing pin and give out flame & ignite the powder charge. Paper pellet primers were later replaced with metallic cup, which are known as percussion caps. The percussion cap is manufactured by sheet of copper, brass, cupro-nickel alloy, or gilding metal of appropriate thickness.

The primer mixture is highly sensitive to heat, pressure, impact, and friction.

4. **Propellant**

The propellant is a chemical substance, which hurled out the projectile from the firearm due to expansion of large amount of gases. Three types of propellant are used black powder, smokeless powder, and semi-smokeless powder.

5. **Wads**

Wads divide the cartridge case into different compartments, and it prevents the projectile and powder from mixing. Different types of wads are used in shotgun cartridge i.e. Over powder wad, Under powder wad, Air-cushion wad, and Base wad.

- Over Powder wad - Over powder wad is also known as Top wad. It is situated at the top of the cartridge. It is crimped closed at the top to hold everything. It opens when firing takes place and allowing the contents to escape out from the shell. Pellets are hold between over powder and under powder wad.
- Under powder wad – It is located just below the pellets and above the air cushion wad. It separates the compartment of pellets through intermixing.

- Air-cushion wad – It is present in the middle of the shell. It seals the shells and helps in prevents the moisture. It is made from felt, cork, feltine, cardboard and plastics (with air holes).
- Base wad – It is present at the base of cartridge case. It provides support for the primer and controls powder space.

### 1.4 Gun Shot Residue

Once a firearm is fired, a large amount of gases are released and these gases are released from the burning Products of propellant consists of carbon monoxide, carbon dioxide, water and oxides of nitrogen. Apart from these, there are partially burnt, un-burnt and semi-burnt particles from propellant, primer, metallic particles from case and bullet. These types of particles are called GSR (Gunshot Residue) Particles. They are also known as FDR (Firearm Discharge Residue) and CDR (Cartridge Discharge Residue).

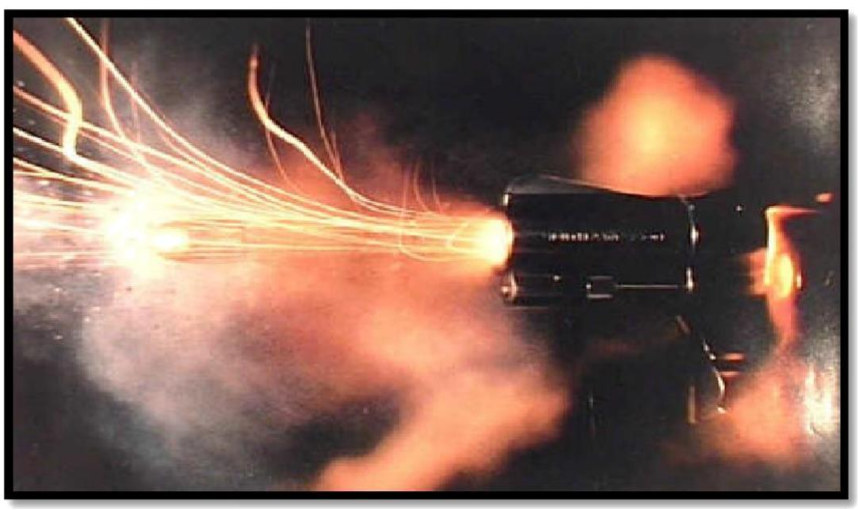


**Fig. 1.28. Gunshot fire producing gunshot residue.**

Once the firing pin hits the percussion cup which contains the mixture of primer, it burns rapidly and ignites the propellant charge. The propellant starts exploding and it produces a great volume of gases, and the components of metal are release from percussion cap in the form of vapor because they are volatilized. Due to its high temperature in the cartridge case, all the charge starts burning and some pieces of un-burnt and semi-burnt particles are left in the size range of 0.1-5 µ. These particles are released out from the barrel of the firearm along with hot gases and disperse in the environment constituting a GSR.

The composition of organic and inorganic materials in the modern 'smokeless powders’ are: -

- Lead, from bullets and primers
- Barium, from primers
- Antimony, from primers
- Copper, from jacket
- Iron from the barrels
- Nitrates, from propellants
- Zinc, from jacket
- Nitrocellulose, from Propellant
- Nitro glycerine, from Propellant

In rifles and shotgun firearms, in self-loading action, then gases will be released out from the ejector and the Gunshot residue may be deposited on the shooter’s hand.

**Forensic Significance of Gun Shot Residue**

Gun Shot Residue plays a very crucial role in the investigation of shooting incidents. Forensic experts carry out the different examinations to identify the firearms and ammunition [33] which determines whether the projectiles and cartridge case were fired from the same firearm or not and carrying out [34], carry out interpretation regarding the wound characteristics [33,34]and perform different chemical tests to estimate the range of fire [34].

One important aspect that frequently requires solution in a shooting investigation is whether an individual has fired a firearm or not. Importance of Gun Shot Residue in the investigation of firearms related cases is increasing now a days. The prime importance of gunshot residue lies in the fact that, GSR evidence can be used to indicate that a person has handled or fired a gun [35] and link them to a firearms crime. It is used to link a suspect to a firearms offence, such as a homicide, suicide. In this respect, Gun Shot Residue evidence is a useful tool in the preliminary examination of criminal investigations, to confirm a suspect's story.[36]

Moreover, Gun Shot Residue can be used to differentiate weather, the firing done from close range and a distant range [37]. This may be done by the analysis of the powder pattern present on the target, and comparison to test firings [38].

The presence of Gun Shot Residue around a entry hole or around the around at a crime scene can be used to identify them as bullet holes [39] Also, in some cases it is possible to differentiate the Gun Shot Residue by chemical composition and thus link it to a various types of ammunition [39-40].

### 1.4.1 Formation of Gun Shot Residue

After striking the pin on the percussion cap, the explosion of primer takes place and there is a release of high pressure and temperature, under high pressure and temperature, the inorganic composition of GSR is vaporized and forced through to escape out from the construction of the firearm as well as through the muzzle end. When it comes in the contact with the air, the composition rapidly cools down and then re-condenses into spherical droplets of GSR.

Moreover, when a firing takes place, unburnt and partially burnt organic propellant powder granules are propelled out of the barrel. Clumping of GSR particles takes place and the size of these particles becomes large. [41] Therefore, GSR consists of a combination of both organic and inorganic residues.

### 1.4.2 Deposition of GSR

Gun Shot Residue particles may be deposited directly as small size particles on the face of shooter, hair, hands, and clothing's of the firer and on the persons and surfaces near the firing area. Gun Shot Residues also stuck on the firearm and cartridge case even after the firing.

The amount of Gun Shot Residue produced, the direction of GSR and distance that GSR travels is highly dependent on which type of firearm and action of the firearm (including barrel length) [42] type of ammunition used, number of shots fired and environmental conditions at the time of discharge).

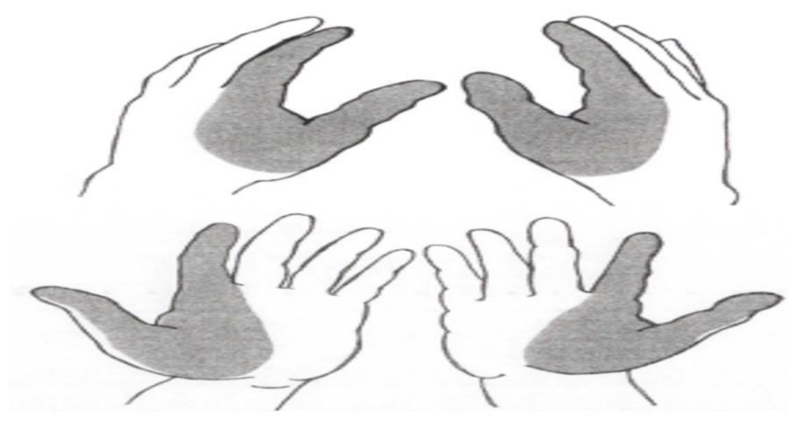


**Figure 1.29.: Common distribution of gunshot residue on hands (DeMaio 1987)**

It has been analyzed that generally the majority of Gun Shot Residue is ejected, propelled out along the trajectory of the projectile, and deposited down the range of firing from the muzzle end, with smaller amount GSR is deposited on the upper surface of the firearm. [39] It is reported that Gun Shot Residue may travel up to several meters from the front end of the barrel [6,11]

The amount of GSR deposited on the firer and the distribution of GSR is also varied by the posture of firing, handling of the firearm, and the nature of the substrate.

(Substrate means the type of clothing worn by the firer) [43]. In some cases, Due to the nature of the firearm and the way of its discharge and subsequent handling of firearm may be such that, GSR particles are in fact not deposited.

The web areas of the firer's hands, shown in Figure 1.28, are generally the areas of highest GSR deposition after discharging a firearm [44]. This is due to the proximity of these areas to the gases escaping along the side or back of the firearm during discharge. The distribution may vary, however, depending on the type of firearm used.

Other areas where GSR is likely to be deposited during a shooting are the firer's forearms or sleeves and the front of the chest [44]

### 1.4.3 Collection of GSR

The collection of Gun Shot Residue is done by various methods. It depends upon the medium from where the GSR has been collected and the technique that will be used to analyze the sample. The method for the collection of GSR should be very simple, it should be carried out quickly, it should be transferable to be easily accessible at scene of crime. The Sampling of GSR should be carried out immediately from the scene of crime due to avoid loss of GSR because of its low persistence.

From the last many years, many techniques have been employed in order to collection of samples from persons, different items in relation to shooting investigations for the analysis of the presence of GSR.

Various techniques include Swabbing, Tape-lifting, Glue-lift sampling and Vacuum lifting (Some studies have compared the available techniques) [44]. The method, which is commonly used for the collection of GSR, is tape-lifting using adhesive sampling discs. The device used for the collection of GSR consists of an aluminum disc (usually 12.7 mm diameter) coated on one surface with double-sided adhesive tape. The discs are pressed gently, adhesive side down, repeatedly and in a systematic manner against the surface to be sampled. The adhesive surface removes gunshot primer residue particles present from the sampling surface and the particles are retained on the adhesive disc for analysis. This technique is a simple, effective, and rapid method of collection of GSR.

The hands are the most common area, where the sample of GSR can be collected after a shooting [38]. GSR can also be collected from other mediums like face and hairs. GSR can be collected from the hair by using comb with cotton wool placed between the teeth of comb. [44]

GSR was successfully recovered for up to 48 hours after the time of firing.

GSR is often collected from another substrate that is clothing. Anadarko and Peterson developed a simple method for collection of GSR from clothing, inside of bags and pockets [44]. The collection of GSR is done by vacuuming through a double filtration system. The disadvantage of this technique is GSR trapped deep within the fabric from previous firings, will be collected.

Motor vehicles are often sampled for the presence of GSR where it is suspected that a firearm has been discharged from within the vehicle (drive-by shooting). In such instances the areas that are sampled will depend on intelligence available as to which window or door the firearm was discharged from. The areas sampled would usually include the window, door lining and roof lining.

In some cases, motor vehicles are sampled for the presence of GSR where it is suspected that the firearm was discharged at some distance away from the vehicle but the vehicle was subsequently used by the offender to escape. In this case, any GSR present would be due to secondary transfer from the offender to surfaces within the vehicle such as the steering wheel, gear lever, hand brake and door handle, and hence these are the areas commonly sampled.

It should be noted that due to the nature of the deposition (via secondary transfer), it is likely that only a small amount of GSR would be transferred to the vehicle. In addition, surfaces such as those mentioned are extremely difficult to sample effectively, due to the shape and material of the substrates.

#### 1.4.4. GSR Collection Kit

A GSR collection kit contains everything which is required for sampling and reduces the chances of contamination [45]. GSR collection kit includes gloves, disposable apron to be worn by the person at the time of sample collection, tweezers, swabs, stubs, containers to store the samples after collection, labels, marking pen, instructions, and a questionnaire to be completed.

#### 1.4.5. Estimation of Range of Fire from GSR Pattern on the Target

From the close range of firing, in handgun, upto 2 ft. (60 cm) and in case of rifle upto 6 ft. Distance, the dispersion Gunshot residues on the target accurately determined the range of firing. when the firearm is in very close contact on the skin, the gun shot residues is not present. To correctly examine the bullet hole, it is important to locate the wound whether it is partially burnt, un-burnt propellant particles and semi-burnt particles within the tissues.

At distance ranges, the dispersion of gunshot residue components on the target can be used to accurate estimation of range of firing.

The pattern of GSR is significantly influenced by various factors including the different muzzle-to-target angles, firing distances, type of ammunition and weapon parameters, caliber and barrel length [46]. These observed effects can conveniently be split into three main groups: -

- **Scorching**

  Scorching is done by the red hot gases as they emit out from the muzzle end of the weapon. Although they initially leave the barrel at a temperature of around 2000°C, they rapidly cool and at a distance of not more than an inch, their scorching effect will be insignificant [12]. The affected area is also very localized being no more than a ¼ inch round the periphery of the bullet entry hole.

The effect of scorching is also dependent upon:

- Surface condition of the target –The effect of scorching will be reduced if the surface is wet.
- Powder type – The Propellent which is double base burns much hotter.
- Pressure produced – degree of scorching is directly proportional to the pressure produced.
- Weight of propellant – If the weight of the propellant is greater, the volume of gas is produced is also greater.

- **Blackening**

This is caused by the incomplete combustion of the propellant. It is mainly composed of amorphous carbon including the partially burnt particles. This effect begins when scorching finishes and can be up to 10 inches (25 cm) from muzzle in rifles and 5 inch (12.5 cm) in pistols. The weight of propellant obviously affects the degree of blackening in the same way as scorching. Blackening is only a light surface coating and is very easily removed with water or by rubbing with a cloth. Thus, absence of blackening cannot be considered as a proof of estimation of firing range.


**Fig. 1.30. Blackening on target surface**

- **Tattooing:** -

Being heavier than the carbonaceous particles, the propellant particles can be found on the target at much greater distances. Using microscope, these particles can be detected up to 30 inch for a handgun and 45 inch for a rifle. More efficient the cartridge and longer the length of the barrel, the fewer the propellant particles that will be discharged from the muzzle end. These particles adhere very strongly to the cloth and show a much better result than the blackening.


**Fig. 1.31** **Tattooing on target surface**

## 6. New Ammunition Types

A number of manufacturers have developed newer types of ammunition that are lead or heavy metal free. [14] These developments are in response to indications that a build-up of lead and other heavy metals in indoor firing ranges presents a potential health hazard to frequent users at the firing range [14,16].

One Australian study [47] examined the elevated lead levels in blood of a recreational shooter over time as well as looking at other sources of lead in blood. They stated that the lead concentrations of the subject far exceeded any that they had found in several hundred environmentally exposed subjects.

Some examples of these new ammunitions are Sintox, CCI Blazer, CBC Clean range and Winchester Ranger [46]. Limited research has been conducted to investigate the physical and chemical characteristics of these lead and heavy metal free ammunitions [47].

### 1.6.1. Inorganic Analysis for Detection of GSR from New Ammunition types

Until a few years ago, most of the techniques available for detecting and characterizing GSR were based on the inorganic heavy metal primer components of the ammunition. From the information available, it is suspected that the main inorganic constituents of gunshot residues derived from heavy metal free and lead-free ammunitions are not specific to GSR.

This creates the problem of distinguishing these particles from environmental and occupational contamination. Consequently, it appears likely that the applicability of SEM/EDX and other inorganic techniques to the detection of these types of gunshot residues is restricted

Although not commonly encountered at scenes of crime at present, a dramatic increase in the use of these ammunitions over recent times, by law enforcement agencies and gun enthusiasts, will no doubt lead to an increase in the chance that they will be encountered in casework situations.

### 1.6.2 Organic Analysis

The Future of GSR Analysis? The significant challenges for inorganic analysis techniques have therefore necessitated the development of techniques that target other compounds present in the GSR from heavy metal free ammunitions. One potential approach is to target the detection of the organic components of the residue.

The organic components mainly stem from compounds in the propellant and some compounds in the primer. Limited research has been carried out on a number of organic techniques however at present no technique has been universally accepted and no standard exists for analyzing the residue from these ammunitions.

Midkiff, discusses the need for the development of a new technique based on the detection of the organic propellant component of ammunition in a three part series of papers titled 'The Changing Face of Firearms Residue Testing'. He states: 'From the perspective of the laboratory the problem is that widely accepted tests for firearms residues have been based on the presence of lead, from the bullet and primer, barium, and antimony. The latter two have formed the basis for bulk elemental analysis techniques. Particles containing all three have become the standard for definitive identification of residue on the hands. Environmental concerns and newer technology are sweeping aside the elements on which we rely. In the next few years, metal based GSR identification will begin to lose its utility. What do we do then? ' The advantage of a technique developed for the organic analysis of gunshot residue is that it could be used for both gunshot residue from heavy metal free ammunition and standard ammunition, as the technique is not dependent on the primer composition [48]

It is an attractive approach as the number and variation of organic additives present in modem propellants may provide the potential for characterizing the ammunition type from the residue detected [48]

It should be noted that techniques developed for analyzing organic gunshot residue may also prove useful for the analysis of organic explosives, as they are often similar in nature. Similarly, existing procedures for the analysis of some types of explosives are helpful when investigating organic GSR because many of the compounds overlap or have strong similarities. Therefore, consideration of the literature regarding the analysis of organic explosives is valuable in the development of a new technique for the analysis of gunpowder residue [48]

Several different types of analysis have been investigated for the detection and identification of both organic propellant traces and explosives. These techniques include high performance liquid chromatography, gas chromatography, capillary electrophoresis, thin-layer chromatography, fluorimeter, and supercritical fluid chromatography. A combination of different detectors has been utilized with these instruments to optimize sensitivity and selectivity.

### 1.5 Scanning Electron Microscopy/Energy Dispersive X-Ray (EDX)

The technique said to have been originally investigated by the Metropolitan Police Forensic Laboratory, New Scotland Yard, in England in the late 1960's [49] suggested in the literature in the 1970's [50-51], and in general analytical chemistry, AAS has been superseded by ICP-MS, currently accepted as the most definitive method for detecting and characterizing GSR particles, is scanning electron microscopy coupled with energy dispersive X-ray analysis (SEM/EDX) SEM/EDX provides a sensitive, non-destructive and highly selective method of analysis). In SEM/EDX the sample is placed in a chamber under vacuum, in the path of a focused electron beam. The electron beam scans the surface of the sample and interacts with atoms in the sample. Signals subsequently emitted from the sample can be detected and used to characterize it.

Secondary electrons provide a means of producing a high-quality image of the sample topography. Backscattered electrons emitted from the sample produce image brightness in proportion to the atomic number at each point on the sample, as high atomic number nuclei backscatter more electrons than lower atomic number nuclei.

X-rays emitted from the sample are characteristic of the emitting atoms and thereby provide a means of determining the elemental composition of the sample. Taking advantage of this, SEM is often coupled with EDX, where an X-ray spectrometer detects and sorts the emitted X-rays based on their energy. The resultant spectrum displays peaks whose position relates to energy (and therefore elemental composition) and height relates to concentration.

The distinct advantage of SEM/EDX over the bulk elemental analysis techniques is that it is a non-destructive technique that characterizes individual GSR particles through observation of the morphology of the particle in combination with analysis of the chemical composition.

Like the bulk elemental techniques, detection of GSR by SEM/EDX is based on the presence of lead, antimony and barium from the ammunition primer. However, while the bulk elemental analysis techniques only allow a total quantity of each of the elements to be determined, using SEM/EDX it is possible to determine whether each of the elements observed are present in a single particle. This provides SEM/EDX with distinct selectivity in comparison to bulk elemental analysis.

A SEM has an energy source that produces a beam of electrons. The primary electron beam interacts with the sample through a collision, such that electrons are emitted from the sample. This process releases energy in the form of characteristic X-rays. An EDX detects and displays these effects.

As X-rays are characteristic for a specific element, they can be used to provide details of the elemental composition of the particles. Figure 1.10 shows an example of a spectrum produced by the EDX for one particle detected in a sample with the use of a SEM, used to provide details of the elemental composition of the particles.

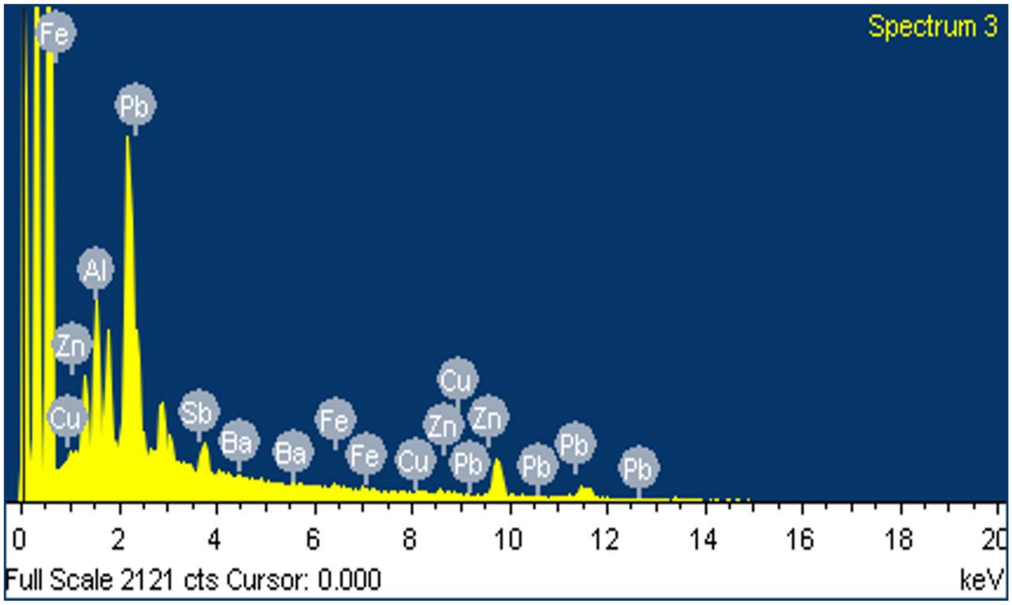



**Fig. 1.32.** __Showing the spectrum of EDX__

Morphology, that is shape, size, and physical appearance, is an important but secondary criterion (after elemental composition) for GSR identification, as it can vary greatly. The majority of GSR particles produced are spheroidal or irregular in shape. It is not consistent with the mechanisms of GSR formation to find particles with crystalline shape (defined shapes with sharp comers).

GSR particles are generally molten in appearance and between 0.5 and 5.0 microns (µm) in size, although particles of up to 100+ microns have been observed [52]. Larger particles are created in the firearm discharge but are lost quickly and are therefore not usually retained for collection and detection.

A further advantage of analysis by SEM/EDX is that the standard tape-lifting sample collection technique was simply adapted so that the adhesive sampling discs most commonly used today are in fact standard SEM/EDX 12.7 mm diameter stubs that can be placed directly into the SEM chamber for examination.

The main disadvantages of utilizing SEM/EDX for the manual detection of GSR are that it is time consuming, tedious, and prone to analyst fatigue. This can result in particles being overlooked and consequently in false negative results. These problems occur because of the small size and number of particles present in comparison to the sample area that requires analysis.

These disadvantages were addressed to some extent with the advent of techniques for the concentration or filtration of particles onto a smaller area for searching [49]. Since then, the disadvantages have largely been overcome by the advent of automated instruments, that allow unattended screening of SEM stubs followed by manual confirmation of suspected GSR particles by the scientist.

In addition, Halberstam (1991) determined a simplified probability equation assessing the probability of finding further gunshot primer residue., when only a portion of a specimen is searched. As a result, some laboratories no longer analyze the entire surface of the sampling device.

In 1994, the ASTM Committee E-30 developed the 'Standard Guide for Gunshot Residue Analysis by Scanning Electron Microscopy/Energy-Dispersive Spectroscopy' ASTM Standard E 1588 - 94 (ASTM 1994).

This document, which underwent a major review in 2008 (ASTM 2008) and has recently had a new version issued (ASTM 2010), sets out a protocol for the sample preparation, sample analysis area, operating parameters, manual analysis, and automated analysis by SEM/EDX, together with data interpretation.

The review of the ASTM Standard (ASTM 2008) acknowledged the use of environmental SEM or low pressure/low vacuum SEM analysis used by some laboratories to remove the requirement of carbon coating to prevent sample charging.

It is important to note here that both the bulk elemental analysis techniques and SEM/EDX technique described above, currently used for the detection of GSR), specifically target the heavy metal primer component of the residue.

## 1.6. OBJECTIVE OF THE RESEARCH WORK

The **first objective** of this research work is to obtain representative background data for a GSR database at different range of different calibre on different substrate from country made and standard firearms.

The **Second Objective** of this research work is to find out the calibre and range of firearm via morphology of GSR through Scanning Electron Microscope.

The **Third Objective** of this research work is to determine the elemental composition of GSR element at different range and different calibre of Country and Standard firearms.

# **CHAPTER -2**

# **REVIEW OF LITERATURE**

# 2. <u>Review of Literature</u>

In this chapter, efforts have been made to provide an overview of the research done on the various facets of Gunshot Residue. The Review literature is very important in a new research topic because previous research study has their own specific purpose. The motive of research work is to find out answers of questions by the scientific procedure. The main Purpose of the research is to find the reality which is hidden and not has been discovered yet. This chapter contains an overall review of research studies which conducted both in India and outside the India in a proper chronological order related to the research problem. Some of the studies that deserve mention are:

(Sharma, 2012), Mentioned in his book "Firearms in criminal investigation and trial" Firearm as a device that can be used to hurl a projectile by great force. The chapter on firearms includes the history of firearms "in which all the primitive as well as modern firearms have been included. According to the author the first firearm was just a long metal tube closed at one end and open at the other known as the cannon. The first proper firearm was the match lock. The various types of firearms along with their parts have been discussed and the most common and essential parts common to all the firearms are the barrel, action, and the grip (butt). The four main types of firearms are shotguns, pistols, revolver, and rifle. Difference in the working of shotguns and rifles are described and the main difference in shotguns and rifles is the presence of land and grooves (rifling) inside the barrel of rifles which cause the stability and accuracy of the projectile fired.

The main emphasis is on the types of ammunition and its composition. The main components of an ammunition are primer mixture, propellant, projectile, cartridge case and wads (only in case of shotguns). Various composition of primers has been told but the recently used primer in India is a mixture of:

Lead Styphnate 32-42%

Antimony sulphide 13-17%

Barium nitrate 27-37%

PETN 4-6%

Tetracene 3-5%

Aluminium 6-8%

The propellants have evolved through the years with black powder being the initial one and smokeless powder being the latest one. The cartridges of shotguns and rifles differ in their projectiles. Rifles fire cartridges having bullets as projectile whereas shotguns (smooth bored firearms) fire cartridges with multiple lead shots (pellets) or a single lead ball (slug).

Another chapter contains the improvised firearms (also known as the country-made firearms). This chapter deals with all the details of an improvised firearm and how it is different from standard firearms in various aspects. The main concern of this chapter is to explain that the country made firearms are made from locally available materials in a rough way. The barrel of improvised firearms is made from pipes, rods, etc readily available. Improvised firearms generally do not have any special chambers and the barrel end serves as the chamber. The bore diameter is not accurately made; hence more than one calibre ammunition can be fired from a single firearm. Identification of firearms in this case is easy as the firearms are not properly finished which leaves unique marks on the bullet as well as cartridge cases. These marks can be easily studied using a comparison microscope and identification of firearm can be done easily. But one firearm cannot be used to standardize all the country-made firearms as they are manufactured roughly with no proper technique.

Another important chapter carried by this book is the chapter on range of firing. This chapter contains the various methods by which range of firing can be estimated in standard firearms. Some of these methods include ejecta inside the wound, muzzle pattern, scorching, blackening, tattooing, GSR, metallic residues, pellet pattern, etc. presence/absence as well as pattern and intensity of these factors act as the major source of estimation of range of firing.

**(**Heard, 2008), The information in the field of ballistics which includes the history of firearms, various types of arms and ammunitions, their various aspects of examination, etc. Gunshot residue (GSR) is produced as an incandescent material when a weapon is fired. The Gunshot residue is mainly the combustion product of primer and propellant. GSR also contains partially burnt, un-burnt and semi-burnt propellant particles. GSR distribution on the target and surrounding environment highly depends upon the kind of firearm. In case of self-loading pistols and revolvers, the GSR escapes the ejection port and gets collected on the hands of firer. Situation is a bit different in case of rifles and shotguns where GSR on the hand is not a common phenomenon. GSR is deposited on the target as well up to a certain range depending on the kind of firearm. GSR can also be found on the objects which came into the path of the bullet and near it. Gunshot residue can be detected and identified by many chemical and instrumental methods which include dermal nitrate test, Walker test, Griess test thin layer chromatography, gas chromatography, atomic absorption spectroscopy, scanning electron microscope. These tests also help a great deal in estimating the range of fire and examination of entry/exit bullet holes.

(Wilber 1977), The method of estimation of the distance of firing from a handgun in Wilber book entitled, "**Ballistic Science for the Law Enforcement Officer"**. Author stated that the importance of “examination of GSR pattern and smudginess which lefts on the skin or on the cloths”. When a firearm was discharged, it hurled out the bullet from the barrel along with a mixture of burnt, unburnt and semi-burnt powder, gases, lubricant, and metal dust".

He further stated that: These rough concentric areas vary in the diameter with distance of the muzzle end to the target. This is difficult to establish standards for powder patterns as related with the distance of the firing.

(Monessen and Starrs,1995), The authors stated that, the deposition of GSR may vary with the firearms, in the fourth edition book titled **"**Scientific Evidence in Civil and Criminal Cases". At any firing distance performed, it would have to bean approximation rather than the exact measurements. In other words, if the victim was fired in the area covered by the clothing, these clothing must be used to compare the measurements rather than Gunshot powder burns on the skin under the cloths. Still, there is no exact table or formula yet to use in the determination of the range of firing of a particular firearm was held from the target when it was fired. This can also happen that the same firearm may produce varying gunshot residue patterns from the same distance. This can easily be examined by test firing the firearm three to five times from the same distance to insure the reliable results.

Federal Bureau of Investigation (2003), used a hand book entitled “Handbook of Forensic Science**”** the following is mentioned in the book**:** The gunshot residue deposition on different evidences such as clothing, it vary with the distance from the muzzle end of the firearm to the target. The dispersion Patterns of gunshot residue can be forged by using a questioned firearm with ammunition combination fired into test materials at known distances. These patterns can be used for the estimation of muzzle-to-target distances.

(Zuzannabrozek-mucha**,** March 2008)**,** He Worked on SEM-EDX study of inorganic Gunshot residue pattern fired from P-64 & P- 83 pistols and Makarov9mmammunition. He collected set of seven samples from the firer hands directly after fired various numbers of experimental shooting with the use of different substrate materials. All samples were analyzed under SEM-EDX. The author finds that total no: GSR particles found was different for different samples of the experimental studied sample sets. Some similarity in ratio of no: of particles of certain elemental composition were observed.

(Solehahazman *et.al.*, 2010), Author worked on the "Analysis of presence of Gunshot Residue and diameter of bullet hole on different substrate"**.** The Sample substrate used for these studies were 6mm wood board (n=10), 18mm wood board (n=10) and tiles (n=10). Each sample surface was shot from 10 feet using 9mm full jacketed meal bullet in semi-automatic pistol. Sodium rhodizonate test was performed to determine the presence to determine the presence of GSR on surface. They observed that the presence of GSR on the surface of 9mm tiles, significant difference between 6mm board and 8mm board. The presence of Gun Shot Residue was observed on all sample substrate surfaces and difference in the diameter of entrance hole of bullet's were observed between 16mm tiles surface substrate and 18mm wood board substrate. When compared with bullet exit hole, the difference between the surfaces of the 16mm & 18mm wood board were also different.

(Ingardena. *et.al*.,2010), Author worked on, “The Chemical and Morphological study of GSR persisting on the shooter by means of SEM/EDX.. The Samples were collected in nine-time interval after a single shot with a large 9mm pistol from five and examined with SEM/EDX. The Number of GSR particles, frequencies of their occurrence and the size of GSR in their time interval were studied. Large number of GSR particles were found in the samples which were collected from hands of shooter, but they go down decreasing with time. Those samples which are collected from the face, small GSR particles were formed, but they stay similar level longer. Those samples which are collected from long interval after shooting, those particles are of smaller size and irregular shapes

(Lindsay.*et.al*.,2012), Author conducted a screening test for GSR using desorption electrospray ionization mass spectrometry (DESI-MS) and SEM. Author noticed that except from the inorganic GSR particles, the shooting of a firearm liberates a number of very specific organic compounds such as methyl and ethyl centralite. The Scanning Electron Microscope samples also need to be scan GSRprior to its SEM-EDX analysis, this is a very rapid and non- destructive technique. The author also proposed a method, which is based on desorption electrospray ionization sampling, which can be applied on stubs, skin or in other substrate.

**(**Lake.*et.al*, 2012), Author used the video spectral comparator 2000 (VSC 2000) to determine Gun Shot Residue particles on clothing. The vsc 2000 is a completely computerized camera system which is equipped with different lightning source and filters, which enables to visualize the small objects in IR range wavelengths and also to observe the fluorescence effects. Author can also work on the usability of the equipment in making IR and fluorescence images of macroscopic GSR deposition patterns.

(T Plattner.*et.al*,2003), Author worked on the "Effect of GSR dispersion patterns on skin from contact angle and near contact angle of gunshot wounds"**.** The Purpose was to inspect the shape and soot direction which deposits with respect to the target muzzle angles, firing distance, type of ammunition used and firearm and its barrel length. Author concluded that Gun Shot Residue on the target surface can also be differentiated by 'inner' and outer gunshot residue powder soot zone. The outer zone is less visible than the inner region and outer powder soot increases with size and decrease in density. In angled shots the inner zone shows an eccentric, elliptic shape which points towards the muzzle end. The outer powder zone is points away from the muzzle end in the contact angle and close contact angle.

(Gerard.*et.al*, 2O17), Performed a test in an indoor shooting range to observe the distance of Gun Shot Residue particles can travel**.** Samples was collected up to 18m. The author observed that the number of Gun Shot Residue particles were found adjacent to the ejection port. An individual near the path of the projectile and with 13.5 m of the muzzle end may be more contamination.

(Julia Polovkopva.*et.al*, 2015), The HS-9 and Cal. 9*19 pistols and Sintox ammunition having forensic markers of 9mm Luger PEP II using gallium and 9mm Luger Action 4 using Gadolinium as marking substance in the gun powder were used. To study the spreading of GSR cloud, high speed photography was employed. Firing was done at different range of 10cm (short distance) and 25cm (long distance) and the GSR on the surface of cloth, barrel, Shooter's hand and cartridges was collected on SEM-stubs and analyzed under SEM-EDX equipped with EDAX analyzer. The GSR analysis of the PEP II ammunition primer showed that it contained Zinc and titanium, and no marking substance (gallium) was present but the same was detected in the thorough EDAX spectral analysis of gunshot powder. While the Action 4 ammunition detected the combination of Zinc (Zn), titanium (Ti) and Gadolinium (Gd) in its primer and Zinc, titanium and Gallium in few cases of the gunshot powder (predominantly in combination with tin and copper). In short distance shooting from PEP II ammunition, Ti, Ga and Zn elements were detected in the GSR but were absent in long distance shooting. But in Action 4 ammunition, Gd, Zn and Ti elements were found in the GSR particles in both short and long-distance shooting. Firing range was estimated by firing on cotton fabric pieces from a distance of 0cm, 5cm, 10cm, 30cm, 50cm, 100cm and chemo graphic methods were applied for copper and zinc visualization. These findings helped in asserting a clear difference between both the type of ammunitions. Also, it concluded that it is a better choice to add marking substances directly into the primers than in gunpowder, in order to prevent any ambiguity.

The secondary movement or transfer of gunshot residue, i.e., How the GSR particles or the trace evidence move away from their site of origination to a secondary surface which is not in its vicinity or is at a distance to it, if they do so then what size of particles are involved in the same, and what all are the practical implications during the investigation of GSR evidences. This whole procedure is conducted through SEM-EDX analysis.

A 9mm SIG Sauer, self-loading pistol using grain jacketed 9-mm Luger 95 9P1 soft point ammunition was used for firing and sampling was done after deriving samples from the hands of the subjects. Firing was done in different scenarios, involving-

I. Straight Firing,

II. Firing followed by handshake and,

III. firing after exchanging firearm.

The analysis of sample was done using JEOL JSM-6480LV, attached with an Oxford INCAGSR (Inca X-Sight Energy Dispersive Spectrometer and automated GSR detection and analysis software). GSR particles were found to be maximum in scenario (I) then in scenario (II) followed by scenario (III). The size of GSR particles were almost similar in scenario (I) and scenario (II) and was comparatively smaller in scenario (III). This article proves that secondary transfers do take place and analysis of the number and size GSR particles would help in the interpretation of GSR evidences.

The composition of the inorganic GSR depends upon the type of primer, propellant, bullet, cartridge case and any GSR present inside the barrel due to previous firings. In this work, comparative study of primer mixture and GSR is done to identify suspected cartridges. The experiment employed Hammerli 280(.32S&WL), S& W 4006 (.40S & W) and Glock 17 (9 mm Luger) semi-automatic pistols and a .38 Special (S & W MOD 649-2) revolver. After test firing, the samples were collected from the shooter’s hand, spent cartridge case and the target surface. The GSR or the primer mixture obtained was analyzed under JSM-5410LV SEM (Scanning Electron Microscope) and LINK ISIS EDX (Energy Dispersive X-ray Spectrometry) to obtain the compositional and morphological data.

Out of 25, 17 cartridges were non-corrosive primer type that contained lead styphnate, antimony sulphide and barium nitrate in addition to elements like Aluminium, Calcium, Silicon, and phosphorus. Seven other lead-free primers were found to have Potassium, Zinc Magnesium. During the quantitative analysis of GSR, it was found that each cartridge from same test firing had a variable concentration of elements. The GSR particles obtained from gun, target and hands were spheroidal in shape but irregular in spent cartridge case. It was found that the elemental composition of GSR depends upon the composition of primer as major elements found in the GSR were in accord to their respective primers. (Hsien-Hui Meng and Hsei-Chang Lee.,2007),

(H. Brown.et.al., 1999), Establishing a relationship between the firing range, and the distribution and amount of gunshot residue with the help of light microscopy (LM) and automated image analysis (IA) which is an easier method to measure GSR on skin samples. A Ruger .22 semi-automatic rifle and high speed CCI solid point ammunition was used for firing on pig skin, with firing range lying from contact to 45cm (2.5, 5, 10, 20, 30, 45cm) with 30 trials at each range. The210 samples derived were prepared for analysis by sectioning and staining with Alizarin Red Stain (ARS), a metallic dye, which highlights the GSR particles. To study the distribution of GSR particles, mean total area of GSR deposition was calculated. The relationship between the gunshot residue deposited within and around the gunshot wound, and the firing range, was assessed by plotting the firing range against the mean GSR deposit area. It was observed that as the firing range was increased, the GSR deposition decreased, showing a non-linear relationship. There was drastic difference in GSR deposited in all the shot ranges, i.e., between contact and 2.5 to 45cm and between 20cm & less and 30cm or above. Also, in case of contact and close-range firing at 2.5cm, heavy concentration of GSR was found in the wound tract. Statistical testing of the obtained relationship showed that it is possible to differentiate between the contact shots & distant shots and in between close range of up to 20 cm and more above 20cm, based on these findings.

**(**ZuzannaBrozek-Mucha*et.al*.,2011), The chemical composition and size of gunshot residue deposited in the vicinity of the shooting person, when fired using 9 *18 PM ammunition, was analyzed using SEM-EDX. The samples were collected from different ranges between 0-100cm including the clothing and hands of the shooting person. Black bovine leather or cotton fabrics were used to cover the target. In case of cotton fabric targets, 5 to 10 cm radius circles were taken to collect micro-traces. The result of the examination done, in respect of number of particles, their chemical classes and dimension proportion, showed a dependence on distance from the muzzle of the gun, both in the shooting and opposite direction. The gunshot residue describing parameters differed on the type of the target substrate. The information derived helps in establishing an understanding of the basic rules of gunshot residue dispersion in the vicinity and surroundings of the shooting gun. Thus, it may help in reconstructing the shooting incidences and in getting an estimation about the mutual directions or positions of the shooter or targets involved in the incident.

The chemical and physical analysis of the gunshot residue deposited in the close surroundings of a sub machine gun fired with and without a sound suppressor was done. The target was covered by cotton fabric or either a porcine skin which resembled human naked skin and clothes. Experiments were performed on them with a machine gun using an ammunition of calibre 7.65 mm browning, keeping the shooting range between 0 to 30 cm. The inorganic and organic residues thus derived were then examined using infrared spectroscopy, optical microscopy and Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectrometry (EDX). The paper discusses the effect of factors like shooting distance, sound suppressor, the type of substrate on the mechanism of the spread of particles and their availability for further research. *(*

(NarayanP. Waghmare.*et.al.*,2004**).** The blackened residue pattern of the bullet is studied and examined by conducting test firings on a target of glass and paper layers by an Indian spotting rifle and ammunition of .315”/8mm calibre. The study revealed the presence of elements like antimony, lead and silicon. Samples obtained from the target’s surface were then examined under Scanning Electron Microscope and Energy Dispersive X-ray Spectrometry (SEM-EDX). The blackened residue pattern is discussed with respect to the hole size, distance between the shooter and the target, and the direction of firing. This study done, helps in avoiding any confusions and mistakes related to the use of Indian spotting rifle and ammunition of .315”/8mm calibre**.**

(Maxwell Abedi. *et.al*.,2021), The gunshot residue obtained after shooting a firearm, as it first passes through a barrier, and it’s use in determining the distance of firing. The methods involved in the estimation of the same include the use of chemical methods like Walker test and the application of atomic absorption spectrometry with addition to other methods as well. Firing was done by a cal. 6.35 PPU98 WALTER MTPH pistol on a target of white clean cotton fabric from different range, to trace the characteristic gunpowder in the vicinity of the projectile’s trajectory. Relevant facts are also derived from the information obtained from this experiment, which helps in the evaluation of certain crimes.

(Mohamed Izzharif.*et.a*l.,2010) discussed the pattern of the gunshot residue particles is studied by conducting firing on a target of cotton cloth with a close firing range of 3 to 12 inches. A semi-automatic pistol and a revolver with SME (Syarikat Malaysia Explosive) and Winchester ammunitions were used to conduct firing. When fired by semi-automatic pistol using 9 mm SME ammunition, a higher and larger amount of completely burnt GSR particles were observed on the target. A confirmatory altered Griess test revealed the presence of considerable quantity of nitrite residue in the GSR particles. When the same was examined under Scanning Electron Microscope, the micrograph obtained showed a 2.6 micrometer mean particle size having spherical shape. On the contrary, when fired through a revolver, with 0.38 SME special ammunition, the GSR particles were small in quantity and the altered Griess test also revealed a small amount of nitrite in it. While using 0.38 Winchester special ammunition, the GSR particles were high in quantity, large with a mixture of completely unburnt, completely burnt and partially burnt particles. The Scanning

Electron Microscope micrograph showed irregular cluster grains having 3.3 micrometer mean diameter. The detection of the presence of lead particles around the bullet entry hole was also positively done by using Sodium Rhodizonate test.

(ZuzannaBrozek-Mucha. *et.al.*, 2001) author examined of the gunshot residue of six different pistols was done which were each fired by six people. The GSR samples were collected form their hands through aluminum stubs having black carbon adhesive tabs. The morphology and elemental composition of the GSR particles was then studied under SEM-EDX. The primer residue was used for the comparative study of the same. A percentage was calculated and expressed, representing the type of class of chemicals detected and the total amount of detected particles. Using non-statistical methods in all the ammunition types studied, it was found that there is a difference between the frequency of a certain chemical class. One ammunition type from another ammunition type was differentiated by applying non-parametric statistical methods like Pie-Kendal and R-Spearman correlation

coefficients. These examinations revealed the presence of certain chemical class of the primer residues in different types of ammunitions, using which different ammunitions could be differentiated based on the chemical and physical examination of their GSR.

(Lawrence. 1993) examined Blount Inc. Cascade Cartridge Industries (CCI) Blazer 'Lead-Free' (LF) and 'Clean-Fire' (CF) ammunition. They noted that Blount Inc. CCI and RWS (Dynamite-Nobel) ammunition primers are described as not containing lead, antimony, or barium, while Fiocchi lead free ammunition is described as still containing antimony and barium. The CCI Blazer ammunition consists of a non-reloadable aluminum case with 4 LF' or 'CF' marking, a Berdan style primer with twin flash holes, and an organic diazo dinitrophenol (DDNP) priming composition.

The exhaust is said to consist of carbon monoxide, carbon dioxide, water, nitrogen, and strontium oxide. The CCI primers are distributed wholesale but not retail for reloading. They are used with either a full metal jacket (FMJ), a total metal jacket (TMJ) with enclosed base, or with hard cast lead bullets. The authors noted that the CCI fired cartridge cases are very clean and even look unfired, with very little shooting. Analysis by SEM/EDX revealed the presence of strontium (the authors suggesting that this was from strontium nitrate) and titanium. The paper also discusses related issues with firing range testing. They carried out GCMS of the primer organics extracted in methanol.

(Harris, 1995) also describes the analysis of primer residue from CCI Blazer Lead Free ammunition by SEM/EDX. They describe the ammunition as TMJ and list the primer components as tetracene (sensitizer), DDNP (initiator), smokeless powder (fuel) and strontium nitrate (oxidizer). Using SEM/EDX, strontium was primarily detected, with some particles containing traces of barium and most being in the 0.5 to 10 µm size range with a spherical morphology. No titanium was detected. Carry-over of standard PbSbBa particles from previous firings was noted by the authors, with more of these present than strontium particles, even after extensive cleaning of the firearm. The presence of composite particles, i.e. PbSbBa, was also observed.

(GunaratnamHimberg. 1994**),** Author examined LF Sintox ammunition from Dynamite Nobel AD. Sintox ammunition typically contains 15% of DDNP and 3% of tetracene as primary explosives, 50% of zinc peroxide as the oxidiser, 5% of 40 micrometer in size titanium metal powder, and 27% of nitrocellulose in the propellant powder. Analysis by SEM revealed spherical particles of GSR mainly consisting of titanium metal and zinc metal. They noted the importance of morphology in distinguishing these from an environmental source. However, a smaller number of spheroidal particles were detected than with standard ammunition. They also mentioned the occurrence of composite (e.g., TiZnPbBa) particles even though a clean firearm was used.

(Haag l 989a; Haag 1995), He carried out two related studies in 1989, he examined residue from lead free CCI Roark Industries centrefire pistol ammunition by SEM/EDX and described it as being composed of zinc and manganese containing particles. In 1995, he looked at Blount CCI Blazer Lead Free, Speer Lawman Clean Fire, Winchester Super Unleaded and Federal Premium Non-Toxic ammunitions. Fired cartridge case residue from each ammunition type was analyzed by SEM/EDX. No lead, barium or antimony was detected in any of the residue samples. Strontium was detected in both the CCI and Speer ammunition residues. Potassium was detected in the Winchester ammunition residues. Calcium and silicon were the only elements detected in the Federal ammunition residue. Haag also used the standard sodium rhodizonate test to look at the effect on firing range estimation. He noted that he could still detect lead on all samples tested, likely arising from carry-over from previous firings. Additionally, he recorded bullet and cartridge case characteristics, and carried out velocity tests for each ammunition type.

(Oommen Pierce. 2006), characterized four types of ammunitions. Post-firing residues of Winchester, Remington/UMC, Federal and Speer LF ammunitions, at different distances from a target, from shooter's hands and from the direct ignition of primers, were examined by SEM/EDX. The results showed that most samples also contained traces of Sulphur and calcium. Ammunition Tested Winchester Win Clean Remington Lead Less Federal Ballistic clean Speer Lawman Clean

Fire Residue Detected K, Na, Al, Si, Cu, Zn K, Na, Al, Si, Cu, Zn Ba, K, Na, Al, Si, Cu, Zn Sr, Al, Si, Cu, Zn.

(Martiny.*et.al*. 2008), characterized the GSR from two generations of Brazilian lead-free CBC (Companhia Brasileira de Cartuchos) ammunition, marketed as Clean Range centrefire cartridges in the United States and Europe. The first-generation Clean Range ammunition demonstrated spherical strontium based GSR particles. In contrast, the second-generation Clean Range ammunition demonstrated irregular GSR particles consisting mainly of potassium, aluminum, silicon and calcium. Authors finally concluded that the identification of Gun Shot Residue originates from the second-generation of Clean Range ammunition on the hands of suspects.

(Snow 1992; Snow 1995) author describes the issues with lead poisoning and the development of lead and heavy metal free ammunitions. In 1992, he described CCI Blazer ammunition similarly to previous authors. The ammunition consists of a tough heat-treated iodized aluminum case coated in Teflon for ease of extraction. It has a Berdan DDNP based primer with twin flash holes and is used in conjunction with a thick copper TMJ projectile (no exposed base). He stated that the original TMJ ammunition was not accurate enough but that the manufacturer had fixed this with a second swage operation. He also mentioned the clean appearance of fired cartridge cases from this ammunition. He noted that DDNP is slightly less sensitive to impact than lead styphnate, therefore less ignition-reliable and dependent on the mechanical condition of the handgun. DDNP has a lower flame temperature and higher pocket gas pressure than standard primer compositions.

(Jain.*et.al*., 2004) conducted a technical study on the Indian homemade firearms (country made firearms) commonly known as 'katta'. He carried out his study on 300 firearms received in CFSL, Chandigarh from June 1984 to June 2003. He studied the characteristic features of .315/.303 inch country made pistol, 12 bore pistols, and .32/.38-inch country made revolver. The various parts of a country made pistol were studied along with their characteristic features. He explained that the barrels are generally made up of pipes or iron rods. The barrels are rough and generally oversized or undersized rather than being of the exact size of the ammunition. This caused the leakage of propellant hence making the firearm less efficient and dangerous to handle. The body of these firearms were coated by brass, steel, and tin. The mechanism of action was made by joining various materials and parts. Hence, it was concluded that the home-made firearms are made by non-standard techniques and can fire two or more closely related ammunitions. These firearms are so poorly finished that their individualization through cartridge cases or bullets can be easily done. But determination of firing range cannot be done effectively as they are not standardized.

(Modi.*et.al*., 1984) explained the difference between country-made pistols and standard firearms. In case of barrel and breech block face, the country made firearms have lots of irregularities which cause more clear and distinct breech block face marks and striation on the cartridge case and bullet respectively. These marks are less clear in case of standard firearms which makes their individualization difficult. When range of firing is to be determined, it is quite difficult in case of country made firearms because the firearms are manufactured in non-standard conditions and the barrels are often oversized or undersized. Due to this, the GSR dispersion cannot be estimated. It entirely depends on the type and condition of firearm. This does not happen in standard firearms, because their GSR dispersion is quite similar among the type of firearm and firing range used. He also explained the differences in other aspects such as pellets distribution, penetration capability, etc.

(Nag and Sinha.1992) conducted a study on estimation of firing range from gunshot residues in standard firearms. He stated that GSR is transported through two ways on the target which are direst GSR transportation (GSRI) and bullet GSR transportation (GSRII). Next, he explained the differences in GSR pattern on the target when the firing is done from close range and long range. GSRI is deposited on the target only from close range firing and can be identified by its radial distribution around the bullet hole.

(Halim.*et.al.*2010) conducted an analysis of gunshot residue deposited on cloth target. The main objective of this article was to estimate shooting distance by visual examination, chemical tests and scanning electron microscope. In visual examination, it was seen that the GSR was deposited maximum from close range firing and the deposit decreased as the range increased. In Griess test, the nitrite formed after complete burning of smokeless powder is examined. The intensity of orange colour formed as the result decreases as the firing range increases. It was concluded that muzzle-to-target distance can be estimated upto 12 inches using various techniques in case of standard firearm.

**(Dietrich. 2012)** carried out a study on the influence of weapon on the distribution of gunshot residues. He studied the formation of plume after firing and distribution of gunshot residue from eleven (11) different pistols with high-speed video analysis. On firing, the initial jet of particles and gas is influenced mainly by the barrel length, calibre and jet velocity. Shape of muzzle is an important factor as it decides the ejection of gunshot material. The gap between barrel and drum also influences the deposition of GSR as more gaps can cause leakage of GSR which would result in a decreased amount of GSR deposition on the target and more GSR on the shooter's hand. Projectile emission influences the GSR distribution in the environment.

(Hodges. 2008), conducted an experiment to determine the range of a firearm. For this purpose, she fired from various distances and compared gunshot residue patterns made on the victim or target. The purpose of this study was to establish, is there any difference on GSR pattern of using different types of firearms and ammunition from distance firing. The findings of research indicates that there is no significant differences observed with different firearms but there were significant differences observed with different brands of ammunition.

(Khudbudin.*et.al.*,2016) demonstrated a method for the determination of range of firing distance which is based on pellet distribution on target surface. Author test fired at various distances viz. 2, 8, 10, 20, 26 ft from the pipe gun to compare gunshot residue pattern and a pellets distribution pattern formed during the test firing. Gun Shot Residue from the target collected and analyzed and analyzed under the scanning electron microscopy and energy dispersive X-ray spectroscopy. Author observed the difference in their chemical composition and morphology of GSR. This study reveals that from the 2 ft distance, blackening and tattooing were observed and from the 8 ft distance spreading of lead pellets can be seen.

(Santos.*et.al.*, 2015) conducted a research study to determine the range of shooting distance by .32 pistol. Firing can be done on the cotton cloth target of size (35 cm × 35 cm), and the GSR deposited on the target surface can be cut into rectangular piece of size (1 cm × 1 cm) and the sample were analyzed under inductively coupled plasma-mass spectrometry (ICP-MS). The data obtained were used to frame a mathematical formula to estimate the range firing distance. The good results were obtained with the samples collected from the radial distances within 2.0–3.0 cm from the bullet entrance hole. By using this Using this, it is possible to accurately (± 6cm) estimate the range of firing distance in the interval [20–90] cm from the target.

# CHAPTER-3

# MATERIALS AND METHODS

# 3. Materials and Methods

This research work was conducted at Central Forensic Science Laboratory, CBI, New Delhi. There were two main objectives of the study, which contains the mathematical as well as the forensic science part. This study combination will help to get a clear vision of Gun Shot Residue evidence, to evaluate evidence and give testimony evidence in the court.

Firearms are used in a wide variety of crimes, including assault, armed robbery & murder. In India, more than 70% of the cases, home made guns are used due to easily available and their low price. Majority of the cases are committing using 7.65mm & .315"/8mm calibre of country made pistol. The blacksmiths who made country made firearms cannot be able to made proper firearm because of lack of tool kits, machines and their knowledge and the experts are facing lots of difficulties in establishing the correct range of firing, calibre and type of weapon, where country made firearms are used in crime. This study may be helpful in revealing the accurate determine of range of firing, calibre and weapon type, where the range of firing is to ascertain in case of country made firearms as well as standard firearms

## 3.1. Classification of different calibre of country made firearms

Thus, broadly these two calibres of country made firearms i.e.,0.315/8mm and 7.65mm were selected for the present study.

### 3.1.1. <u>Relevant Features of 0.315/8mm and 7.65mm country made firearms</u>

1. Even though the .315/8mm and 7.65mm pistols were manufactured to load the cartridge into the chamber, and there are many variations found in the weapon like barrel length of the weapon, diameter of muzzle and breech end.
2. The length of the barrels of 7.65 mm were varied from 8.25cms (app.) up to 24.38cms (app.) likewise muzzle diameter of the barrel varied from 0.78cms to 1.18cmswhereas in .315"/8mm length of the barrel were varied from 20 cms (app.) to 60cms (app.)

**Table 3.1. <u>Showing Specification in Barrel length and Muzzle diameter of 7.65mm and .315"/8mm country made firearm</u>**

| **Specification** | 7.65mm | .315"/8mm |
|---|---|---|
| **Barrel Length** | 96mm to 70-110mm (app.) | 640 mm to 120-160 mm (app.) |
| **Muzzle Diameter** | 0.78cms to 1.18cms (app.) | 0.98cms to 2.4cms (app.) |

**Table 3.2. <u>Showing Specification of Overall length and weight of .315"/8mm Standard and country made Firearms</u>**

| | **Standard Firearm** | **Country made Firearm** |
|---|---|---|
| **Specification** | .315"/8mm | .315"/8mm |
| **Overall length** | 1,117 mm | 200mm to 260 mm |
| **Weight** | 3340gm | 700gm |

**Table3.3. Showing Specification of Overall length and weight of 7.65mm Standard and Country made firearm**

| | Standard Firearm | Country made Firearm |
|---|---|---|
| **Specification** | 7.65mm | 7.65 mm |
| **Overall length** | 167 mm | 200 mm to 400 mm |
| **Weight** | 710 gm | 650 mm to 750mm |

In this order to perform the experiment, Aluminium tape, Forceps, Stubs, Recovery box, Chart Paper, white cotton cloth, cardboard stick to hold the paper and cotton cloth. Two types of 7.65mm and .315"/8mm calibre of country made, and standard firearms are used for shooting test. The ammunition was used of KF (Khadki Factory, Pune). In order to perform chemical tests, Beaker, Test tube, Spray bottle, Filter paper and cotton swab were used. A canon digital camera D60 was used to photograph the GSR image.

## 3.4 SAMPLE SIZE

Two types of .315"/8mm and 7.65mm calibre of standard and country made pistol were used for test firing. The ammunition of KF (khadki factory), Pune were used for test firing. Total 720 (seven hundred twenty) samples were collected from .315"/8mm and 7.65mm calibre of both country made and standard firearm on cloth and paper substrate from different ranges i.e., 4", 8" and 12". Thirty (30) times firing was done from the same distance with different firearms.

**Table 3.4. Showing Sample Size Data**

| 7.65mm calibre | | | | | | | | .315"/8mm calibre | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard firearm | | | | Country made firearm | | | | Standard firearm | | | | Country made firearm | | | |
| Cloth Substrate | | Paper Substrate | | Cloth Substrate | | Paper Substrate | | Cloth Substrate | | Paper Substrate | | Cloth Substrate | | Paper Substrate | |
| 4" | 30 | 4" | 30 | 4" | 30 | 4" | 30 | 4" | 30 | 4" | 30 | 4" | 30 | 4" | 30 |
| 8" | 30 | 8" | 30 | 8" | 30 | 8" | 30 | 8" | 30 | 8" | 30 | 8" | 30 | 8" | 30 |
| 12" | 30 | 12" | 30 | 12" | 30 | 12" | 30 | 12" | 30 | 12" | 30 | 12" | 30 | 12" | 30 |

### 3.4.1. Country-made Firearm

Three hundred sixty (360), country-made firearms of 7.65 mm and .315"/8mm were used for firing on the target cloth and paper substrate. These firearms were obtained from the cases received in the Central Forensic Science Laboratory, CBI (New Delhi). one hundred eighty (180) samples were collected from 7.65mm country made pistols on both paper and cloth substrate from different ranges i.e., 4", 8" and 12". One hundred eighty (180) samples were collected from .315"/8mm country made pistol on both paper and cloth substrate from different ranges i.e., 4", 8" and 12".

### 3.4.2. Standard Firearm

Three hundred sixty (360), standard firearms of 7.65 mm and .315''/8mm were used for firing on the target cloth and paper substrate. These firearms were obtained from the cases received in the Central Forensic Science Laboratory, CBI (New Delhi). one hundred eighty (180) samples were collected from 7.65mm standard pistols on both paper and cloth substrate from different ranges i.e., 4", 8" and 12". One hundred eighty (180) samples were collected from .315''/8mm sporting rifle on both paper and cloth substrate from different ranges i.e., 4",8" and 12".

### 3.4.3 Cartridges

720 cartridges of 7.65mm and .315''/8mm were used for firing. The cartridges were obtained from case property as well as the laboratory stock. Each firearm was fired from three ranges of 10 cm, 20 cm and 30 cm on the target.

### 3.4.4. Cloth

Cotton cloth of white color was used as target on which firing is done in criminal cases to get better vision and study of dispersion pattern of GSR around the bullet hole. The dimension of each cloth sample was taken as 32 x 35 cm.

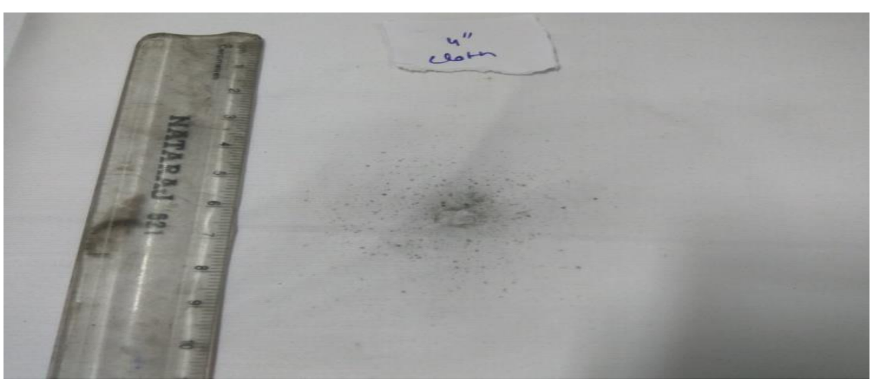
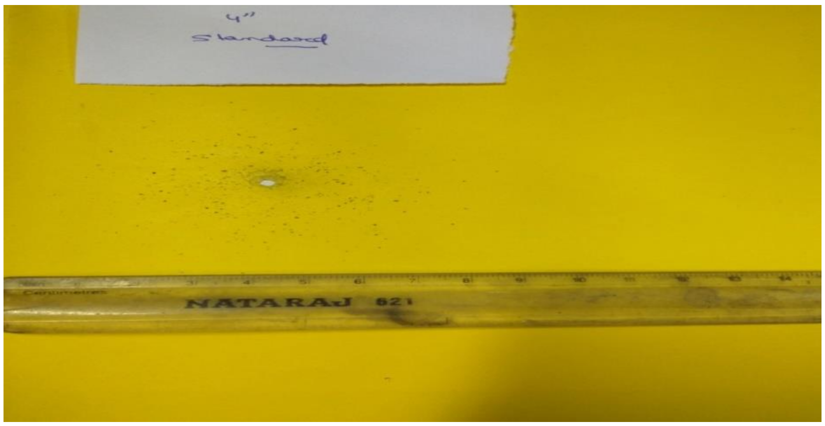


**Fig. 3.4 Sample Cotton Cloth**

## 3.4.5. <u>Paper</u>

Chart paper of yellow color was used as target on which firing is done in criminal cases to get better analysis of study of dispersion pattern of GSR around the bullet hole. The dimension of each cloth sample was taken as 32 x 35 cm.




**<u>Fig. 3.5. Sample Chart Paper</u>**

## 3.4.6. <u>Bullet Recovery Box and Firearm Mount</u>

The cloth and paper samples were fixed on hardboard which was mounted on the bullet recovery box present in the firing room of CFSL (CBI), New Delhi. Bullet recovery box isa long box made up of aluminium and iron with bundles of cotton tightly packed inside it. It is the box in which all the firings were carried out safely and the bullet can be recovered from it. The firearm was mounted on a firearm mount as country-made firearms can be highly dangerous if fired from hands. There are chances of barrel getting burst or any kind of mis-happening may occur. Hence, to avoid any such condition the firearm is fired after being mounted.


**Fig. 3.6 Bullet recovery box to which the cloth sample was mounted**

## Table 3.5. Showing types of ammunition used

| Number | Headstamp Codes | Calibre | Manufacturer | Country |
|---|---|---|---|---|
| 01 | 7.65 kF | 7.65mm | Khadki Factory | India |
| 02 | .315”/8mm KF | .315”/8mm | Khadki Factory | India |

## 3.6. Target Material and Firearm Preparation

The study was done in an indoor firing range of ballistics division, using .315”/8mm and 7.65mm calibre of standard and country made pistol. The KF ammunition was used for test firing, which is manufactured by khadki factory, pune, make with jacketed bullet. Ten KF (khadki factory, pune) ammunition, .315”/8mm and 7.65mm cartridges were used for firing from each firing distance. The targets were made up of sheet of chart paper and cotton cloth having size of 45cm X 45cm (app.), fitted on cardboard sheet by cello tape having size of 40cm X 40cm (app.). The cardboard was fixed to recovery box; recovery box was 120 cm above the ground. The firearm was fixed in the stand, in front of target and their position adjusted at different distances according to the firing range. Test firing were conducted in the firing room of CFSL/CBI/New Delhi from three different distances i.e., at 4", 8" and 12" on the target from each of 7.65mm and .315"/8mm country made and standard firearms. Thereafter GSR pattern on the chart paper and cotton cloth targets were collected carefully. A digital camera was used for photographed the images. After that dispersion pattern of GSR was calculated by visual method by taking the outer radius of the circle (outer radius of the circle was taken from the centre of the circle to the outer dispersion line) and then inner radius of the circle (inner radius was taken from the centre of the circle to the inner dispersion line) and put the formula of area of circle ($A = \pi r^2$). By using this formula, we can find out the dispersion pattern area of the Gun Shot Residue.

**Fig.3.7. <u>Target Material and Firearm Preparations</u>**

## 3.7. Shooting Test

The purpose of the Firing test was to determine the range of firing from muzzle end to the target. The distances were chosen close ranges which were 4, 8 and 12”. These distances were chosen because good result of GSR were found only in close range (Jeffrey, 1998). The distances were repeated nine times to get better result.

The Laboratory set-up and test firings were performed under the guidance of Specialist Senior Scientific Assistant, Mr. R. Chauhan, at CFSL/CBI/New Delhi. After calculating the dispersion pattern area of the Gun Shot Residue, the sample is further proceeding for the instrumental analysis. The Scanning electron microscope, model Zeiss EVOMA10 equipped VEGA 3LMU/EDX (Energy Dispersive X-ray) was used for analysis of morphology of GSR Particles.

**Fig. 3.8. Firing Range**

## 3.8. Chemical Test

### 3.8.1. Modified Griess Test

For modified Griess test, fresh Griess reagent was prepared with 0.5g of Sulphanillic acid and 0.2g of α-naphthylamine. Put them into two separate beakers containing 70ml of water and heat until they mix completely. After mix, cool them and add 30ml of acetic acid. Then 1:1 ratio of α-naphthylamine and sulphanillic acid taking into a beaker and put the solution on filter paper. Then the sample was put on the filter paper and pressed. If Pink colour appears on the paper indicates the presence of nitrite residue.

## 3.9. Instruments

SEM (Scanning Electron Microscope) model ZEISS quanta 200F with XJ Microscope control software and EDX (Energy Dispersive X-ray) detector model oxford instrument X-MAX were employed for morphological and elemental composition of GSR particles.

**Fig.3.9. SEM/EDX**

**Fig. 3.10. Sample Area**

### 3.9.1. <u>SEM/EDX ANALYSIS</u>

SEM was employed to analysis the morphology and characteristics of Gun Shot Residue particles. Sample size was cut near the bullet hole which contained high amount of GSR Particles of size 1X1 cm (app.). Stubs was properly clean with ethanol. Aluminium tape was cut & stick on the stub properly with the help of forceps, so that sample was adjusted on the stub. The stubs were placed in coating chamber for two hours. The analysis was done in high vacuum mode using 1X1 mm of gold and palladium coating. So, that cloth and paper target do not get destroyed. It was adjusted at different magnification for proper microstructure image of GSR particle as well as percentage composition of elements which are present in GSR sample.

**Fig. 3.11. SEM Samples**

**Fig.3.12. SEM Samples Preparation Tray**

# CHAPTER 4

# Result and Discussion

# 4. Result and Discussion

## 4.1. Visual Examination

The determination of firing distance was first observed on the basis visual examination on the cotton cloth and the paper target at different distance fired by different calibre of standard and country made firearms. The dispersion pattern was irregularly circular. To find out the dispersion Pattern area, first we can draw two circles, one circle is drawn near the outer dispersion pattern area and another circle is drawn near the inner dispersion pattern area. Now, the dispersion pattern area was calculated by taking the outer radius and inner radius (Outer radius was taken from the centre of bullet hole to the outer dispersion area and the inner radius was taken from the centre of bullet hole to the inner dispersion area), then the area of outer circle and inner circle was calculated by using the formula ($A = \pi r^2$) . By using this formula, the area of dispersion pattern of .315"/8mm and 7.65mm caliber of country made and standard firearms was calculated. It will help in determining the range of firing and caliber of country made and standard firearms.

How calculation of area of dispersion pattern was done to be demonstrated by taking an example, to be illustrated:

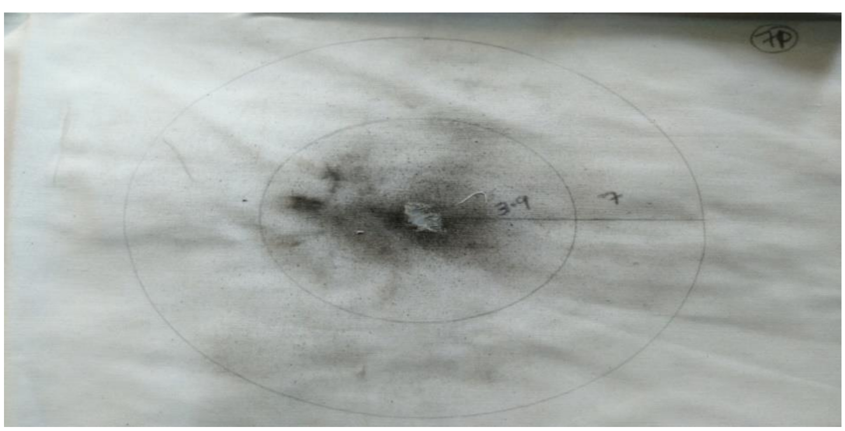



**Fig. 4.1. Showing Area of dispersion pattern on Cloth Sample**

In this fig, first we can draw outer circle near the outer dispersion pattern area, then we can drawn inner circle near the inner dispersion pattern area with the help of compass by taking bullet hole as a centre, the radius of the circle was calculated with the help of ruler.

### 4.1.1 Area of outer dispersion pattern

Radius= 7 cm

Putting the value of radius in the formulae of area of circle ($A = \pi r^2$),

value of $\pi$ is 3.14, A= 3.14 x 7cm x 7cm = 53.38 cm$^2$(app.)

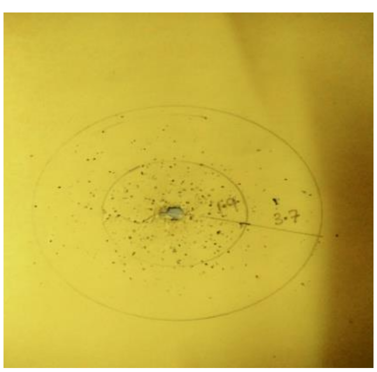
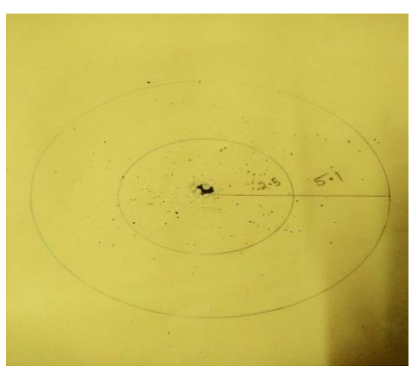
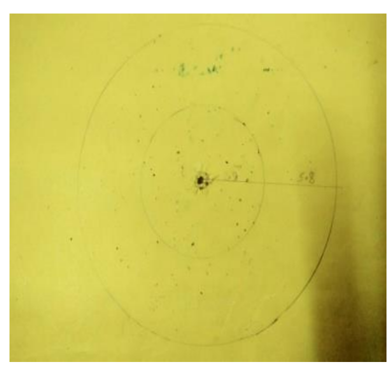
### 4.1.2 Area of inner dispersion pattern

Radius= 3.9 cm

Putting the value of radius in the formulae of area of circle ($A = \pi r^2$),

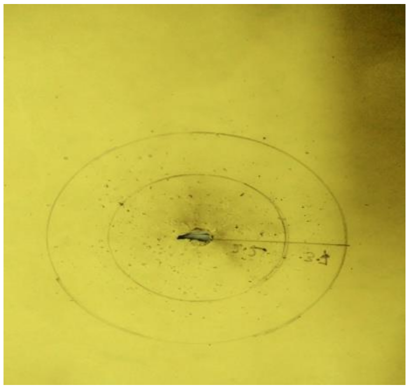
Value of $\pi$ is 3.14, A= 3.14 x 3.9cm x 3.9cm = 47.75 cm$^2$ (app.)

**Fig.4.2. Showing the dispersion pattern of 7.65mm standard firearm on Paper Target**

| 4” Range | 8” Range | 12” Range |
|---|---|---|
|  |  |  |

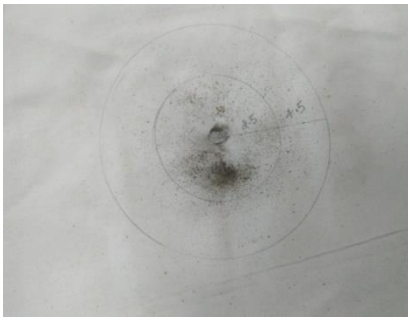
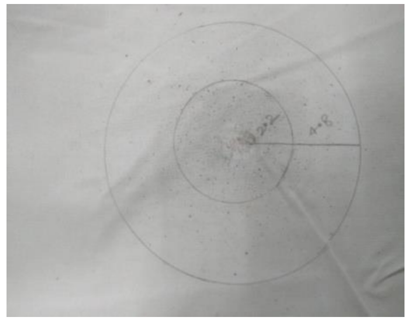
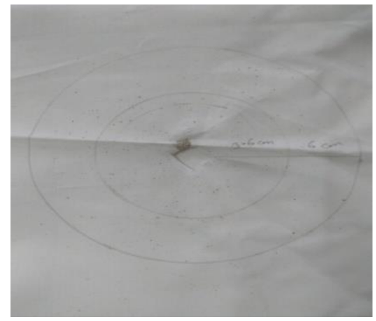
It is observed that at 4” range, more deposition of GSR near the bullet hole, and less dispersion pattern is seen, as the range of firing increases, deposition of GSR becomes less near the bullet hole and dispersion pattern area increases when range increases.

**Fig. 4.3 <u>Showing the dispersion pattern of 7.65mm country made firearm on paper target</u>**

| 4” Range | 8” Range | 12” Range |
|---|---|---|
|  |  |  |

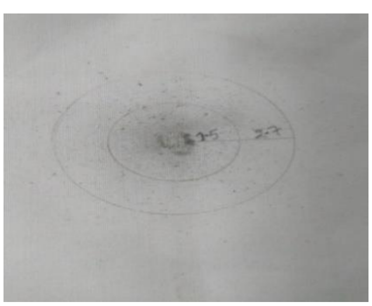
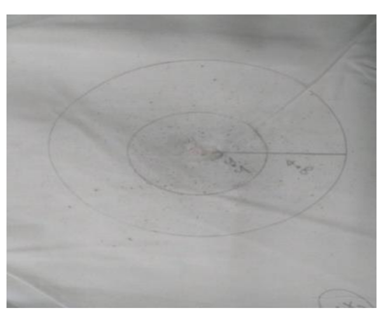
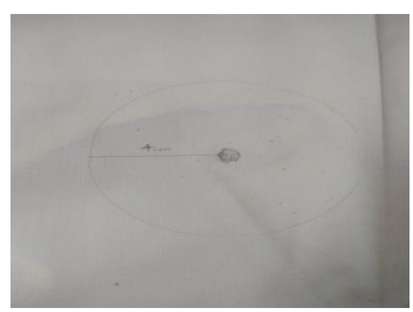
It is observed that at 4” range, more deposition of GSR near the bullet hole, and less dispersion pattern is seen, as the range of firing increases, deposition of GSR becomes less near the bullet hole and dispersion pattern area increases when range increases.

**Fig. 4.4. <u>Showing the dispersion pattern of 7.65mm country made firearm on Cloth target</u>**

| 4” Range | 8" Range | 12” Range |
|---|---|---|
|  |  |  |

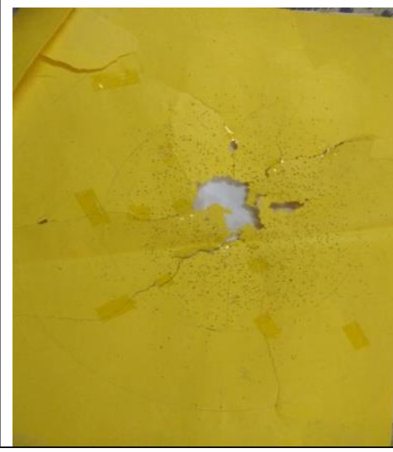
It is observed that at 4” range, more deposition of GSR near the bullet hole, and less dispersion pattern is seen, as the range of firing increases, deposition of GSR becomes less near the bullet hole and dispersion pattern area increases when range increases.

**Fig. 4.5. <u>Showing the dispersion pattern of 7.65mm Standard firearm on cotton Cloth target</u>**

| 4" Range | 8" Range | 12" Range |
|---|---|---|
|  |  |  |

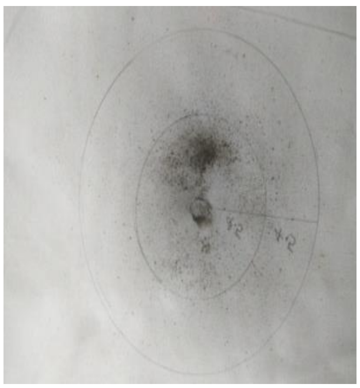
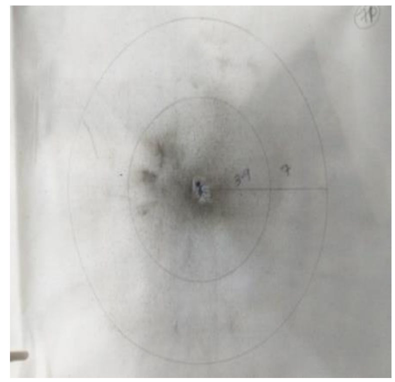
It is observed that at 4” range, more deposition of GSR near the bullet hole, and less dispersion pattern is seen, as the range of firing increases, deposition of GSR becomes less near the bullet hole and dispersion pattern area increases when range increases.

**Fig. 4.6. <u>Showing the dispersion pattern of .315”/8mm country made firearm on paper target</u>**

| 4" Range | 8" Range | 12" Range |
|---|---|---|
|  |  |  |

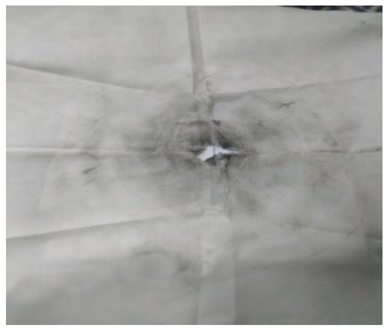
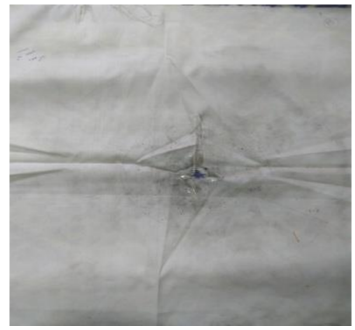
It is observed that at 4” range, The size of bullet hole is large as compared to 8” and 12” distances and deposition of GSR near the bullet hole at 4” distance is less, as compared to 8” and 12” distances.

**Fig. 4.7.** **<u>Showing the dispersion pattern of .315”/8mm country made firearm on cloth target</u>**

| 4" Range | 8" Range | 12" Range |
|---|---|---|
|  |  |  |

It is observed that at 4” range, more deposition of GSR near the bullet hole, and less dispersion pattern is seen, as the range of firing increases, deposition of GSR becomes less near the bullet hole and dispersion pattern area increases when range increases.

**Fig. 4.8. Showing the dispersion pattern of .315"/8mm Standard Pistol on cloth target**

| 4" Range | 8" Range | 12" Range |
|---|---|---|
|  |  |  |

It is observed that at 4" range, more deposition of GSR near the bullet hole, and less dispersion pattern is seen, as the range of firing increases, deposition of GSR becomes less near the bullet hole and dispersion pattern area increases when range increases.

**Fig. 4.9. <u>Showing the dispersion pattern of .315"/8mm Standard firearm on Paper target</u>**

| 4" Range | 8" Range | 12" Range |
| --- | --- | --- |
|  |  |  |

It is observed that at 4" range, nothing was found, the paper target teared off due to high pressure, at 8" distance, paper teased off but dispersion pattern was observed. At 12" distance, more dispersion pattern can be seen and more deposition of GSR was found near the bullet hole. In case of .315"/8mm standard firearm on paper target, as the range increases, dispersion pattern area was increases and deposition of GSR was also increased.

**4.10. Calculation of Outer and inner Dispersion pattern area of GSR on different substrate fired by different ranges of country made and standard firearms.**

**Table 4.10.1. Showing outer and inner dispersion pattern area of GSR on paper target fired by 7.65mm calibre of country made firearm at different ranges**

| Dispersion Pattern Area | Samples | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Range 4” | | | | | | | | | |
| Inner Dispersion Area | 13.2 $Cm^2$ | 12.7 $Cm^2$ | 6.5 $Cm^2$ | 9.8 $Cm^2$ | 11.4 $Cm^2$ | 7.5 $Cm^2$ | 14.7 $Cm^2$ | **8.6** $Cm^2$ | 13.4 $Cm^2$ | 12.4 $Cm^2$ |
| Outer Dispersion Area | 62.4 $Cm^2$ | 54.3 $Cm^2$ | 38.5 $Cm^2$ | 45.2 $Cm^2$ | 49.6 $Cm^2$ | 32.5 $Cm^2$ | 68.4 $Cm^2$ | 73.2 $Cm^2$ | 58.7 $Cm^2$ | 71.4 $Cm^2$ |
| | Range 8" | | | | | | | | | |
| Inner Dispersion Area | 20.6 $Cm^2$ | 22.4 $Cm^2$ | 24.4 $Cm^2$ | 25.6 $Cm^2$ | 27.2 $Cm^2$ | 28.5 $Cm^2$ | 29.4 $Cm^2$ | 23.5 $Cm^2$ | 26.4 $Cm^2$ | 26.8 $Cm^2$ |
| Outer Dispersion Area | 81.7 $Cm^2$ | 80.3 $Cm^2$ | 82.2 $Cm^2$ | 84.4 $Cm^2$ | 89.5 $Cm^2$ | 92.4 $Cm^2$ | 98.4 $Cm^2$ | 82.8 $Cm^2$ | 87.6 $Cm^2$ | 91.6 $Cm^2$ |
| | Range 12" | | | | | | | | | |
| Inner Dispersion Area | 36.4 $Cm^2$ | 35.8 $Cm^2$ | 37.4 $Cm^2$ | 39.4 $Cm^2$ | 42.8 $Cm^2$ | 44.9 $Cm^2$ | 38.3 $Cm^2$ | 40.8 $Cm^2$ | 36.7 $Cm^2$ | 43.8 $Cm^2$ |
| Outer Dispersion Area | 130.21 $Cm^2$ | 122.93 $Cm^2$ | 139.82 $Cm^2$ | 147.67 $Cm^2$ | 159.81 $Cm^2$ | 168.73 $Cm^2$ | 141.35 $Cm^2$ | 151.82 $Cm^2$ | 131.61 $Cm^2$ | 162.94 $Cm^2$ |

Table.4.10.1., Shows the dispersion pattern of GSR of different ranges by 7.65mm country made pistol on Paper target. It is observed that at 4” distance the minimum dispersion area of inner circle was 6.5cm$^2$ and maximum dispersion area of inner circle was 14.7cm$^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 32.5cm$^2$ and the maximum dispersion area of outer circle was 73.2 cm$^2$ respectively.

At 8” distance the minimum dispersion area of inner circle was 20.6cm$^2$ and maximum dispersion area of inner circle was 29.4cm$^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 72.4cm$^2$ and the maximum dispersion area of outer circle was 98.3 cm$^2$ respectively.

At 12” distance the minimum dispersion area of inner circle was 35.8cm$^2$ and maximum dispersion area of inner circle was 44.9 cm$^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 122.4cm$^2$ and the maximum dispersion area of outer circle was 168.4 cm$^2$ respectively.

**Table 4.10.2. Showing outer and inner dispersion pattern area of GSR on paper target fired by 7.65mm calibre of Standard firearm at different ranges.**

| Dispersion Pattern Area | Samples | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Range 4” | | | | | | | | | |
| Inner Dispersion Area | 10.8 $Cm^2$ | 12.7 $Cm^2$ | 14.8 $Cm^2$ | 11.4 $Cm^2$ | 13.7 $Cm^2$ | 10.4 $Cm^2$ | 14.2 $Cm^2$ | 13.2 $Cm^2$ | 12.6 $Cm^2$ | 13.5 $Cm^2$ |
| Outer Dispersion Area | 49.2 $Cm^2$ | 59.5 $Cm^2$ | 69.4 $Cm^2$ | 54.6 $Cm^2$ | 63.7 $Cm^2$ | 48.5 $Cm^2$ | 67.7 $Cm^2$ | 61.4 $Cm^2$ | 58.4 $Cm^2$ | 60.4 $Cm^2$ |
| | Range 8" | | | | | | | | | |
| Inner Dispersion Area | 21.5 $Cm^2$ | 24.6 $Cm^2$ | 23.8 $Cm^2$ | 20.6 $Cm^2$ | 22.8 $Cm^2$ | 24.2 $Cm^2$ | 22.7 $Cm^2$ | 22.9 $Cm^2$ | 24.3 $Cm^2$ | 22.4 $Cm^2$ |
| Outer Dispersion Area | 82.4 $Cm^2$ | 96.4 $Cm^2$ | 92.6 $Cm^2$ | 79.6 $Cm^2$ | 88.7 $Cm^2$ | 95.6 $Cm^2$ | 84.2 $Cm^2$ | 88.4 $Cm^2$ | 95.8 $Cm^2$ | 95.2 $Cm^2$ |
| | Range 12" | | | | | | | | | |
| Inner Dispersion Area | 37.4 $Cm^2$ | 39.6 $Cm^2$ | 44.8 $Cm^2$ | 46.9 $Cm^2$ | 49.2 $Cm^2$ | 40.6 $Cm^2$ | 36.9 $Cm^2$ | 45.7 $Cm^2$ | 48.3 $Cm^2$ | 42.5 $Cm^2$ |
| Outer Dispersion Area | 132.4 $Cm^2$ | 144.8 $Cm^2$ | 160.3 $Cm^2$ | 165.8 $Cm^2$ | 169.4 $Cm^2$ | 152.8 $Cm^2$ | 122.5 $Cm^2$ | 161.6 $Cm^2$ | 167.3 $Cm^2$ | 156.8 $Cm^2$ |

It is observed that at 4” distance the minimum dispersion area of inner circle was 10.4 $cm^2$ and maximum dispersion area of inner circle was 14.8$cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer dispersion area was 49.2 $cm^2$ the maximum dispersion area of outer dispersion area was 69.4 $cm^2$ respectively.

At 8” distance the minimum dispersion area of inner circle was 20.6 $cm^2$ and maximum dispersion area of inner circle was 24.6$cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 79.6$cm^2$ and the maximum dispersion area of outer circle was 96.4 $cm^2$ respectively.

At 12” distance the minimum dispersion area of inner circle was 36.9 $cm^2$ and maximum dispersion area of inner circle was 48.3 $cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 102.4$cm^2$ and the maximum dispersion area of outer circle was 159.4 $cm^2$ respectively.

**Table 4.10.3. <u>Showing outer and inner dispersion pattern area of GSR on cloth target fired by 7.65mm calibre of country made firearm at different ranges.</u>**

| Dispersion Pattern Area | Samples | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Range 4" | | | | | | | | | |
| Inner Dispersion Area | 8.3 $Cm^2$ | 9.2 $Cm^2$ | 12.1 $Cm^2$ | 13.5 $Cm^2$ | 7.6 $Cm^2$ | 14.4 $Cm^2$ | 11.2 $Cm^2$ | 6.8 $Cm^2$ | 10.8 $Cm^2$ | 11.9 $Cm^2$ |
| Outer Dispersion Area | 39.4 $Cm^2$ | 43.1 $Cm^2$ | 52.8 $Cm^2$ | 59.4 $Cm^2$ | 34.5 $Cm^2$ | 54.4 $Cm^2$ | 69.5 $Cm^2$ | 61.3 $Cm^2$ | 66.8 $Cm^2$ | 49.7 $Cm^2$ |
| | Range 8" | | | | | | | | | |
| Inner Dispersion Area | 19.4 $Cm^2$ | 20.8 $Cm^2$ | 29.4 $Cm^2$ | 28.4 $Cm^2$ | 21.5 $Cm^2$ | 28.3 $Cm^2$ | 22.6 $Cm^2$ | 27.6 $Cm^2$ | 26.8 $Cm^2$ | 25.2 $Cm^2$ |
| Outer Dispersion Area | 72.4 $Cm^2$ | 79.6 $Cm^2$ | 98.3 $Cm^2$ | 92.4 $Cm^2$ | 79.3 $Cm^2$ | 91.6 $Cm^2$ | 78.5 $Cm^2$ | 88.4 $Cm^2$ | 84.6 $Cm^2$ | 83.3 $Cm^2$ |
| | Range 12" | | | | | | | | | |
| Inner Dispersion Area | 38.7 $Cm^2$ | 36.9 $Cm^2$ | 40.8 $Cm^2$ | 42.6 $Cm^2$ | 41.8 $Cm^2$ | 39.5 $Cm^2$ | 44.7 $Cm^2$ | 43.3 $Cm^2$ | 40.8 $Cm^2$ | 37.5 $Cm^2$ |
| Outer Dispersion Area | 141.2 $Cm^2$ | 137.2 $Cm^2$ | 151.8 $Cm^2$ | 159.4 $Cm^2$ | 157.7 $Cm^2$ | 148.5 $Cm^2$ | 168.5 $Cm^2$ | 102.4 $Cm^2$ | 151.8 $Cm^2$ | 138.6 $Cm^2$ |

It is observed that at 4” distance the minimum dispersion area of inner circle was 6.8 $cm^2$ and maximum dispersion area of inner circle was 14.4$cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer dispersion area was 34.5 $cm^2$ and the maximum dispersion area of outer dispersion area was 69.5 $cm^2$ respectively.

At 8” distance the minimum dispersion area of inner circle was 19.4$cm^2$ and maximum dispersion area of inner circle was 29.4$cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 72.4$cm^2$ and the maximum dispersion area of outer circle was 98.3 $cm^2$ respectively.

At 12” distance the minimum dispersion area of inner circle was 35.8$cm^2$ and maximum dispersion area of inner circle was 44.9 $cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 122.4$cm^2$ and the maximum dispersion area of outer circle was 168.4 $cm^2$ respectively.

**Table 4.10.4. <u>Showing outer and inner dispersion pattern area of GSR on cloth target fired by 7.65mm calibre of Standard firearm at different ranges.</u>**

| Dispersion Pattern Area | Samples | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Range 4" | | | | | | | | | |
| Inner Dispersion Area | 10.9 $Cm^2$ | 11.8 $Cm^2$ | 12.8 $Cm^2$ | 11.4 $Cm^2$ | 14.9 $Cm^2$ | 13.7 $Cm^2$ | 13.4 $Cm^2$ | 10.4 $Cm^2$ | 14.3 $Cm^2$ | 10.5 $Cm^2$ |
| Outer Dispersion Area | 49.4 $Cm^2$ | 55.4 $Cm^2$ | 60.2 $Cm^2$ | 54.6 $Cm^2$ | 68.4 $Cm^2$ | 63.7 $Cm^2$ | 62.2 $Cm^2$ | 48.5 $Cm^2$ | 68.2 $Cm^2$ | 49.2 $Cm^2$ |
| | Range 8" | | | | | | | | | |
| Inner Dispersion Area | 20.9 $Cm^2$ | 21.7 $Cm^2$ | 24.8 $Cm^2$ | 24.3 $Cm^2$ | 23.8 $Cm^2$ | 21.4 $Cm^2$ | 22.9 $Cm^2$ | 24.2 $Cm^2$ | 23.2 $Cm^2$ | 21.3 $Cm^2$ |
| Outer Dispersion Area | 80.2 $Cm^2$ | 83.2 $Cm^2$ | 96.4 $Cm^2$ | 96.2 $Cm^2$ | 92.6 $Cm^2$ | 81.9 $Cm^2$ | 84.8 $Cm^2$ | 94.2 $Cm^2$ | 91.9 $Cm^2$ | 81.9 $Cm^2$ |
| | Range 12" | | | | | | | | | |
| Inner Dispersion Area | 36.4 $Cm^2$ | 38.2 $Cm^2$ | 42.3 $Cm^2$ | 46.4 $Cm^2$ | 40.8 $Cm^2$ | 39.4 $Cm^2$ | 41.6 $Cm^2$ | 37.5 $Cm^2$ | 39.4 $Cm^2$ | 47.8 $Cm^2$ |
| Outer Dispersion Area | 130.9 $Cm^2$ | 142.6 $Cm^2$ | 155.9 $Cm^2$ | 164.2 $Cm^2$ | 153.2 $Cm^2$ | 143.6 $Cm^2$ | 150.4 $Cm^2$ | 133.5 $Cm^2$ | 143.7 $Cm^2$ | 164.6 $Cm^2$ |

It is observed that at 4” distance the minimum dispersion area of inner circle was 10.4 $cm^2$ and maximum dispersion area of inner circle was 14.9$cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer dispersion area was 48.5 $cm^2$ and the maximum dispersion area of outer dispersion area was 68.4 $cm^2$ respectively.

At 8” distance the minimum dispersion area of inner circle was 20.9$cm^2$ and maximum dispersion area of inner circle was 24.8$cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 80.2$cm^2$ and the maximum dispersion area of outer circle was 96.4 $cm^2$ respectively.

At 12” distance the minimum dispersion area of inner circle was 36.2$cm^2$ and maximum dispersion area of inner circle was 46.4 $cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 130.9$cm^2$ and the maximum dispersion area of outer circle was 164.6 $cm^2$ respectively.

**Table 4.10.5. <u>Showing outer and inner dispersion pattern area of GSR on paper target fired by .315"/8mm calibre of country made firearm at different ranges</u>**

| Dispersion Pattern Area | Samples | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Range 4" | | | | | | | | | |
| Inner Dispersion Area | 73.2 $Cm^2$ | 76.8 $Cm^2$ | 70.6 $Cm^2$ | 78.4 $Cm^2$ | 77.2 $Cm^2$ | 71.9 $Cm^2$ | 79.5 $Cm^2$ | 72.8 $Cm^2$ | 75.8 $Cm^2$ | 76.5 $Cm^2$ |
| Outer Dispersion Area | 217.4 $Cm^2$ | 234.6 $Cm^2$ | 250.5 $Cm^2$ | 276.8 $Cm^2$ | 266.9 $Cm^2$ | 208.6 $Cm^2$ | 254.8 $Cm^2$ | 228.5 $Cm^2$ | 273.5 $Cm^2$ | 267.8 $Cm^2$ |
| | Range 8" | | | | | | | | | |
| Inner Dispersion Area | 89.8 $Cm^2$ | 94.8 $Cm^2$ | 91.7 $Cm^2$ | 85.7 $Cm^2$ | 90.4 $Cm^2$ | 93.8 $Cm^2$ | 88.2 $Cm^2$ | 91.5 $Cm^2$ | 94.2 $Cm^2$ | 87.5 $Cm^2$ |
| Outer Dispersion Area | 308.4 $Cm^2$ | 315.3 $Cm^2$ | 343.8 $Cm^2$ | 354.6 $Cm^2$ | 329.5 $Cm^2$ | 338.6 $Cm^2$ | 347.5 $Cm^2$ | 356.3 $Cm^2$ | 334.6 $Cm^2$ | 328.9 $Cm^2$ |
| | Range 12" | | | | | | | | | |
| Inner Dispersion Area | 115.4 $Cm^2$ | 103.2 $Cm^2$ | 102.6 $Cm^2$ | 113.8 $Cm^2$ | 118.5 $Cm^2$ | 109.2 $Cm^2$ | 115.9 $Cm^2$ | 112.4 $Cm^2$ | 117.5 $Cm^2$ | 102.3 $Cm^2$ |
| Outer Dispersion Area | 380.6 $Cm^2$ | 386.8 $Cm^2$ | 399.3 $Cm^2$ | 391.4 $Cm^2$ | 389.3 $Cm^2$ | 393.6 $Cm^2$ | 106.9 $Cm^2$ | 386.7 $Cm^2$ | 398.3 $Cm^2$ | 381.4 $Cm^2$ |

It is observed that at 4” distance the minimum dispersion area of inner circle was 70.6 $cm^2$ and maximum dispersion area of inner circle was 79.5 $cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer dispersion area was 208.6 $cm^2$ and the maximum dispersion area of outer dispersion area was 273.5 $cm^2$ respectively.

At 8” distance the minimum dispersion area of inner circle was 85.7$cm^2$ and maximum dispersion area of inner circle was 94.8$cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 308.4$cm^2$ and the maximum dispersion area of outer circle was 356.3 $cm^2$ respectively.

At 12” distance the minimum dispersion area of inner circle was 102.3$cm^2$ and maximum dispersion area of inner circle was 118.5 $cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 380.6$cm^2$ and the maximum dispersion area of outer circle was 399.3 $cm^2$ respectively.

**Table 4.10.6. <u>Showing outer and inner dispersion pattern area of GSR on Cloth target fired by .315"/8mm calibre of Standard firearm at different ranges.</u>**

| Dispersion Pattern Area | Samples | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Range 4" | | | | | | | | | |
| Inner Dispersion Area | 126.7 $Cm^2$ | 124.6 $Cm^2$ | 128.9 $Cm^2$ | 111.5 $Cm^2$ | 104.6 $Cm^2$ | 117.8 $Cm^2$ | 127.4 $Cm^2$ | 119.8 $Cm^2$ | 109.5 $Cm^2$ | 116.7 $Cm^2$ |
| Outer Dispersion Area | 560.9 $Cm^2$ | 554.6 $Cm^2$ | 568.3 $Cm^2$ | 539.8 $Cm^2$ | 524.6 $Cm^2$ | 545.6 $Cm^2$ | 564.7 $Cm^2$ | 549.7 $Cm^2$ | 532.6 $Cm^2$ | 541.8 $Cm^2$ |
| | Range 8" | | | | | | | | | |
| Inner Dispersion Area | 147.8 $Cm^2$ | 152.8 $Cm^2$ | 158.8 $Cm^2$ | 142.4 $Cm^2$ | 149.8 $Cm^2$ | 150.5 $Cm^2$ | 146.7 $Cm^2$ | 155.4 $Cm^2$ | 159.7 $Cm^2$ | 144.6 $Cm^2$ |
| Outer Dispersion Area | 598.6 $Cm^2$ | 614.8 $Cm^2$ | 623.5 $Cm^2$ | 586.4 $Cm^2$ | 607.6 $Cm^2$ | 610.8 $Cm^2$ | 594.8 $Cm^2$ | 619.8 $Cm^2$ | 627.8 $Cm^2$ | 590.6 $Cm^2$ |
| | Range 12" | | | | | | | | | |
| Inner Dispersion Area | 176.62 $Cm^2$ | 186.5 $Cm^2$ | 198.4 $Cm^2$ | 208.5 $Cm^2$ | 170.9 $Cm^2$ | 192.6 $Cm^2$ | 179.6 $Cm^2$ | 189.7 $Cm^2$ | 202.5 $Cm^2$ | 194.5 $Cm^2$ |
| Outer Dispersion Area | 678.5 $Cm^2$ | 687.6 $Cm^2$ | 716.8 $Cm^2$ | 725.6 $Cm^2$ | 669.8 $Cm^2$ | 694.5 $Cm^2$ | 681.4 $Cm^2$ | 689.7 $Cm^2$ | 720.9 $Cm^2$ | 705.7 $Cm^2$ |

It is observed that at 4” distance the minimum dispersion area of inner circle was 104.6 $cm^2$ and maximum dispersion area of inner circle was 128.9$cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer dispersion area was 524.6 $cm^2$ and the maximum dispersion area of outer dispersion area was 568.3 $cm^2$ respectively.

At 8” distance the minimum dispersion area of inner circle was 142.4$cm^2$ and maximum dispersion area of inner circle was 159.7$cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 586.4$cm^2$ and the maximum dispersion area of outer circle was 627.8 $cm^2$ respectively.

At 12” distance the minimum dispersion area of inner circle was 170.9$cm^2$ and maximum dispersion area of inner circle was 208.5 $cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 678.5$cm^2$ and the maximum dispersion area of outer circle was 725.6 $cm^2$ respectively.

**Table 4.10.7. Showing outer and inner dispersion pattern area of GSR on cloth target fired by .315"/8mm calibre of country made firearm at different ranges.**

| Dispersion Pattern Area | Samples | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Range 4" | | | | | | | | | |
| Inner Dispersion Area | 88.3 $Cm^2$ | 92.7 $Cm^2$ | 85.8 $Cm^2$ | 93.7 $Cm^2$ | 94.6 $Cm^2$ | 87.9 $Cm^2$ | 90.5 $Cm^2$ | 88.6 $Cm^2$ | 91.5 $Cm^2$ | 80.7 $Cm^2$ |
| Outer Dispersion Area | 269.8 $Cm^2$ | 291.6 $Cm^2$ | 259.8 $Cm^2$ | 283.6 $Cm^2$ | 288.7 $Cm^2$ | 294.7 $Cm^2$ | 259.6 $Cm^2$ | 268.4 $Cm^2$ | 298.6 $Cm^2$ | 251.6 $Cm^2$ |
| | Range 8" | | | | | | | | | |
| Inner Dispersion Area | 109.6 $Cm^2$ | 103.8 $Cm^2$ | 118.5 $Cm^2$ | 108.6 $Cm^2$ | 113.9 $Cm^2$ | 117.5 $Cm^2$ | 105.2 $Cm^2$ | 116.5 $Cm^2$ | 109.5 $Cm^2$ | 115.3 $Cm^2$ |
| Outer Dispersion Area | 376.5 $Cm^2$ | 367.8 $Cm^2$ | 343.4 $Cm^2$ | 358.5 $Cm^2$ | 363.9 $Cm^2$ | 376.5 $Cm^2$ | 363.5 $Cm^2$ | 354.6 $Cm^2$ | 348.4 $Cm^2$ | 379.5 $Cm^2$ |
| | Range 12" | | | | | | | | | |
| Inner Dispersion Area | 138.7 $Cm^2$ | 143.6 $Cm^2$ | 140.9 $Cm^2$ | 148.7 $Cm^2$ | 136.4 $Cm^2$ | 144.4 $Cm^2$ | 132.5 $Cm^2$ | 142.8 $Cm^2$ | 136.5 $Cm^2$ | 147.8 $Cm^2$ |
| Outer Dispersion Area | 437.2 $Cm^2$ | 415.2 $Cm^2$ | 423.8 $Cm^2$ | 446.5 $Cm^2$ | 458.3 $Cm^2$ | 419.5 $Cm^2$ | 412.5 $Cm^2$ | 468.8 $Cm^2$ | 456.3 $Cm^2$ | 447.3 $Cm^2$ |

It is observed that at 4” distance the minimum dispersion area of inner circle was 80.7 $cm^2$ and maximum dispersion area of inner circle was 94.6$cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer dispersion area was 215.6 $cm^2$ and the maximum dispersion area of outer dispersion area was 298.6 $cm^2$ respectively.

At 8” distance the minimum dispersion area of inner circle was 103.8$cm^2$ and maximum dispersion area of inner circle was 118.5$cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 343.4$cm^2$ and the maximum dispersion area of outer circle was 379.5 $cm^2$ respectively.

At 12” distance the minimum dispersion area of inner circle was 132.5$cm^2$ and maximum dispersion area of inner circle was 148.7 $cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 412.5$cm^2$ and the maximum dispersion area of outer circle was 468.8 $cm^2$ respectively.

**Table 4.10.8. <u>Showing outer and inner dispersion pattern area of GSR on Paper target fired by .315"/8mm calibre of Standard firearm at different ranges.</u>**

| Dispersion Pattern Area | Samples | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Range 4" | | | | | | | | | |
| Inner Dispersion Area | - | - | - | - | - | - | - | - | - | - |
| Outer Dispersion Area | - | - | - | - | - | - | - | - | - | - |
| | Range 8" | | | | | | | | | |
| Inner Dispersion Area | 111.3 $Cm^2$ | 104.5 $Cm^2$ | 119.4 $Cm^2$ | 121.6 $Cm^2$ | 106.4 $Cm^2$ | 103.7 $Cm^2$ | 114.3 $Cm^2$ | 113.8 $Cm^2$ | 101.8 $Cm^2$ | 122.5 $Cm^2$ |
| Outer Dispersion Area | - | - | - | - | - | - | - | - | - | - |
| | Range 12" | | | | | | | | | |
| Inner Dispersion Area | 170.5 $Cm^2$ | 185.4 $Cm^2$ | 167.8 $Cm^2$ | 192.5 $Cm^2$ | 196.7 $Cm^2$ | 176.5 $Cm^2$ | 164.7 $Cm^2$ | 189.5 $Cm^2$ | 193.6 $Cm^2$ | 174.3 $Cm^2$ |
| Outer Dispersion Area | 576.8 $Cm^2$ | 625.3 $Cm^2$ | 563.6 $Cm^2$ | 658.4 $Cm^2$ | 678.6 $Cm^2$ | 598.4 $Cm^2$ | 540.6 $Cm^2$ | 648.6 $Cm^2$ | 665.7 $Cm^2$ | 588.6 $Cm^2$ |

It is observed that at 4” distance the minimum dispersion and maximum area of inner and outer circle was nil. Nothing was observed at this distance due to heavy pressure of cartridge. It destroys the target completely.

At 8” distance the minimum dispersion area of inner circle was 101.8$cm^2$ and maximum dispersion area of inner circle was 122.5$cm^2$ while in case of outer dispersion circle, the minimum and maximum dispersion area of outer and inner circle was Nil. Nothing was observed at this distance due to heavy pressure of cartridge. It destroys the target completely.

At 12” distance the minimum dispersion area of inner circle was 164.7$cm^2$ and maximum dispersion area of inner circle was 196.7 $cm^2$ while in case of outer dispersion circle, the minimum dispersion area of outer circle was 540.6$cm^2$ and the maximum dispersion area of outer circle was 665.7 $cm^2$ respectively.

## 4.11. Comparison based on Dispersion Pattern of GSR

**Table 4.11.1. Showing comparison of dispersion pattern area between Cloth and Paper substrate fired by 7.65mm calibre of country made firearm at different ranges.**

- **I.D – Inner Dispersion Area, O.D – Outer Dispersion Area**

| Range | Dispersion Pattern Area | |
|---|---|---|
| | **Cloth** | **Paper** |
| **4"** | I.D : 7-18 Cm$^2$ (app.)<br>O.D : 30-70 Cm$^2$ (app.) | I.D : 7-18 Cm$^2$ (app.)<br>O.D : 30-70 Cm$^2$(app.) |
| **8"** | I.D : 20-30 Cm$^2$ (app.)<br>O.D : 70-100 Cm$^2$ (app.) | I.D : 20-30 Cm$^2$ (app.)<br>O.D: 70-100 Cm$^2$ (app.) |
| **12"** | I.D : 35-45 Cm$^2$ (app.)<br>O.D : 130-170 Cm$^2$(app.) | I.D : 35-45 Cm$^2$ (app.)<br>O.D : 120-170 Cm$^2$(app.) |

**Table 4.11.2. Showing comparison of dispersion pattern area between Cloth and Paper substrate fired by 7.65mm calibre of standard firearm at different ranges.**

| Range | Dispersion Pattern Area | |
|---|---|---|
| | **Cloth** | **Paper** |
| **4"** | **I.D : 10-15 Cm$^2$(app.)**<br>**O.D : 40-70 Cm$^2$(app.)** | **I.D : 10-15 Cm$^2$(app.)**<br>**O.D : 40-70 Cm$^2$(app.)** |
| **8"** | **I.D : 20-25 Cm$^2$(app.)**<br>**O.D : 80-100Cm$^2$ (app.)** | **I.D : 20-25 Cm$^2$(app.)**<br>**O.D : 80-100Cm$^2$ (app.)** |
| **12"** | **I.D : 35-50 Cm$^2$ (app.)**<br>**O.D : 130-170 Cm$^2$ (app.)** | **I.D : 35-50 Cm$^2$ (app.)**<br>**O.D : 130-170 Cm$^2$ (app.)** |

**Table 4.11.3. Showing comparison of dispersion pattern area on Paper substrate fired by 7.65mm calibre of country made and standard firearm at different ranges.**

| **Range** | **Dispersion Pattern Area** | |
|---|---|---|
| **Substrate-Paper** | **Country made pistol** | **Standard pistol** |
| **4"** | I.D : 7-18 $Cm^2$ (app.)<br>O.D : 30-70 $Cm^2$ (app.) | I.D : 10-15 $Cm^2$ (app.)<br>O.D : 40-70 $Cm^2$ (app.) |
| **8"** | I.D : 20-30 $Cm^2$ (app.)<br>O.D : 70-100 $Cm^2$ (app.) | I.D : 20-25 $Cm^2$ (app.)<br>O.D : 80-100 $Cm^2$ (app.) |
| **12"** | I.D : 35-45 $Cm^2$ (app.)<br>O.D : 120-170 $Cm^2$ (app.) | I.D : 35-50 $Cm^2$ (app.)<br>O.D : 130-170 $Cm^2$ (app.) |

**Table 4.11.4. Showing comparison of dispersion pattern area on Cloth substrate fired by 7.65mm calibre of country made and standard firearm at different ranges.**

| **Range** | **Dispersion Pattern Area** | |
|---|---|---|
| **Substrate-Cloth** | **Country made Pistol** | **Standard Pistol** |
| **4"** | I.D : 7-18 $Cm^2$ (app.)<br>O.D : 30-70 $Cm^2$ (app.) | I.D : 10-15 $Cm^2$ (app.)<br>O.D : 40-70 $Cm^2$ (app.) |
| **8"** | I.D : 20-30 $Cm^2$ (app.)<br>O.D : 70-100 $Cm^2$ (app.) | I.D : 20-25 $Cm^2$ (app.)<br>O.D : 80-100 $Cm^2$ (app.) |
| **12"** | I.D : 35-45 $Cm^2$ (app.)<br>O.D : 130-170 $Cm^2$ (app.) | I.D : 35-50 $Cm^2$ (app.)<br>O.D : 130-170 $Cm^2$ (app.) |

**Table 4.11.5. Showing comparison of dispersion pattern area between Cloth and Paper substrate fired by .315"/8mm calibre of country made firearm at different ranges.**

| **Range** | **Dispersion Pattern Area** | |
|---|---|---|
| | **Cloth** | **Paper** |
| **4"** | I.D : 80-95 $Cm^2$ (app.)<br>O.D : 250-300 $Cm^2$ (app.) | I.D : 70-80 $Cm^2$ (app.)<br>O.D : 210-280 $Cm^2$ (app.) |
| **8"** | I.D : 100-120 $Cm^2$ (app.)<br>O.D : 340-380 $Cm^2$ (app.) | I.D : 85-95 $Cm^2$ (app.)<br>O.D : 300-360 $Cm^2$ (app.) |
| **12"** | I.D : 130-150 $Cm^2$ (app.)<br>O.D : 410-470 $Cm^2$ (app.) | I.D : 100-120 $Cm^2$ (app.)<br>O.D : 380-400 $Cm^2$ (app.) |

**Table 4.11.6. Showing comparison of dispersion pattern area between Cloth and Paper substrate fired by .315"/8mm calibre of Standard firearm at different ranges**

| **Range** | **Dispersion Pattern Area** | |
|---|---|---|
| | **Cloth** | **Paper** |
| **4"** | I.D : 100-130 $Cm^2$ (app.)<br>O.D : 530-570 $Cm^2$ (app.) | I.D : -<br>O.D : - |
| **8"** | I.D : 140-160 $Cm^2$ (app.)<br>O.D : 580-630 $Cm^2$ (app.) | I.D : 100-125 $Cm^2$ (app.)<br>O.D : - |
| **12"** | I.D : 170-210 $Cm^2$ (app.)<br>O.D : 650-730 $Cm^2$ (app.) | I.D : 160-200 $Cm^2$ (app.)<br>O.D : 540-600 $Cm^2$ (app.) |

**Table 4.11.7. <u>Showing comparison of dispersion pattern area on paper substrate fired by .315"/8mm calibre of country made and standard firearm at different ranges.</u>**

| **Range** | **Dispersion Pattern Area** | |
|---|---|---|
| **Substrate-Paper** | **Country made pistol** | **Standard pistol** |
| **4"** | I.D : 70-80 $Cm^2$ (app.)<br>O.D : 210-280 $Cm^2$ (app.) | I.D : -<br>O.D : - |
| **8"** | I.D : 85-95 $Cm^2$ (app.)<br>O.D : 300-360 $Cm^2$ (app.) | I.D : 100-120 $Cm^2$ (app.)<br>O.D : - |
| **12"** | I.D : 100-120 $Cm^2$ (app.)<br>O.D : 380-400 $Cm^2$ (app.) | I.D : 160-200 $Cm^2$ (app.)<br>O.D : 540-600 $Cm^2$ (app.) |

**Table 4.11.8. <u>Showing comparison of dispersion pattern area on Cloth substrate fired by .315"/8mm calibre of country made and standard firearm at different ranges.</u>**

| **Range** | **Dispersion Pattern Area** | |
|---|---|---|
| **Substrate-Cloth** | **Country made pistol** | **Standard pistol** |
| **4"** | I.D : 80-95 $Cm^2$ (app.)<br>O.D : 250-300 $Cm^2$ (app.) | I.D : 100-130 $Cm^2$ (app.)<br>O.D : 530-570 $Cm^2$ (app.) |
| **8"** | I.D : 100-120 $Cm^2$ (app.)<br>O.D : 340-380 $Cm^2$ (app.) | I.D : 140-160 $Cm^2$ (app.)<br>O.D : 580-630 $Cm^2$ (app.) |
| **12"** | I.D : 130-150 $Cm^2$ (app.)<br>O.D : 410-470 $Cm^2$ (app.) | I.D : 170-120 $Cm^2$ (app.)<br>O.D : 650-730 $Cm^2$ (app.) |

**Table 4.11.9. Showing comparison of dispersion pattern area on Cloth substrate fired by 7.65mm and .315"/8mm calibre of standard firearm at different ranges.**

| Range | Dispersion Pattern Area | |
|---|---|---|
| **Substrate-cloth** | **7.65mm standard pistol** | **.315"/8mm standard pistol** |
| **4"** | I.D : 10-15 $Cm^2$ (app.)<br>O.D : 40-70 $Cm^2$ (app.) | I.D : 100-130 $Cm^2$ (app.)<br>O.D : 530-570 $Cm^2$ (app.) |
| **8"** | I.D : 20-25 $Cm^2$ (app.)<br>O.D : 80-100 $Cm^2$ (app.) | I.D : 140-160 $Cm^2$ (app.)<br>O.D : 580-630 $Cm^2$ (app.) |
| **12"** | I.D : 35-50 $Cm^2$ (app.)<br>O.D : 130-170 $Cm^2$ (app.) | I.D : 170-210 $Cm^2$ (app.)<br>O.D : 680-730 $Cm^2$ (app.) |

**Table 4.11.10. Showing comparison of dispersion pattern area on Cloth substrate fired by 7.65mm and .315"/8mm calibre of country made firearm at different ranges.**

| Range | Dispersion Pattern Area | |
|---|---|---|
| **Substrate-cloth** | **7.65mm country made Pistol** | **.315"/8mm country made pistol** |
| **4"** | I.D : 7-18 $Cm^2$ (app.)<br>O.D : 30-70 $Cm^2$ (app.) | I.D : 80-95 $Cm^2$ (app.)<br>O.D : 280-300 $Cm^2$ (app.) |
| **8"** | I.D : 20-30 $Cm^2$ (app.)<br>O.D : 70-120 $Cm^2$ (app.) | I.D : 100-120 $Cm^2$ (app.)<br>O.D : 340-380 $Cm^2$ (app.) |
| **12"** | I.D : 35-45 $Cm^2$ (app.)<br>O.D : 130-170 $Cm^2$ (app.) | I.D : 130-150 $Cm^2$ (app.)<br>O.D : 410-470 $Cm^2$ (app.) |

**Table 4.11.11. Showing comparison of dispersion pattern area on Paper substrate fired by standard 7.65mm and .315"/8mm calibre of standard firearm at different ranges.**

| Range | Dispersion Pattern Area | |
|---|---|---|
| **Substrate - paper** | **7.65mm standard pistol** | **.315"/8mm standard pistol** |
| **4"** | I.D : 10-15 $Cm^2$ (app.)<br>O.D : 40-70 $Cm^2$ (app.) | I.D : -<br>O.D : - |
| **8"** | I.D : 20-25 $Cm^2$ (app.)<br>O.D : 80-100 $Cm^2$ (app.) | I.D : 100-125 $Cm^2$ (app.)<br>O.D : - |
| **12"** | I.D : 35-50 $Cm^2$ (app.)<br>O.D : 130-170 $Cm^2$ (app.) | I.D : 160-200 $Cm^2$ (app.)<br>O.D : 540-600 $Cm^2$ (app.) |

**Table 4.11.12. Showing comparison of dispersion pattern area on Paper substrate fired by 7.65mm and .315"/8mm calibre of country made firearm at different ranges.**

| Range | Dispersion Pattern Area | |
|---|---|---|
| **Substrate-Paper** | **7.65mm country made pistol** | **.315"/8mm country made** |
| **4"** | I.D : 7-18 $Cm^2$ (app.)<br>O.D : 30-70 $Cm^2$ (app.) | I.D : 70-80 $Cm^2$ (app.)<br>O.D : 210-280 $Cm^2$ (app.) |
| **8"** | I.D : 30-30 $Cm^2$ (app.)<br>O.D : 70-100 $Cm^2$ (app.) | I.D : 100-120 $Cm^2$ (app.)<br>O.D : 340-380 $Cm^2$ (app.) |
| **12"** | I.D : 35-45 $Cm^2$ (app.)<br>O.D : 120-170 $Cm^2$ (app.) | I.D : 130-150 $Cm^2$ (app.)<br>O.D : 410-470 $Cm^2$ (app.) |

## 4.12. Scanning electron microscopy analysis of GSR particles

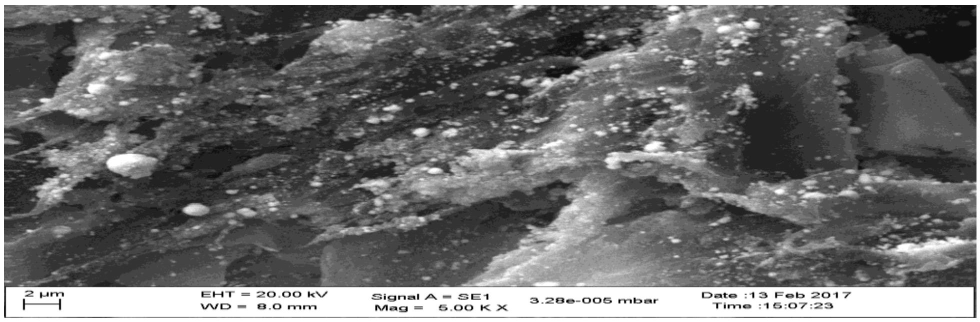
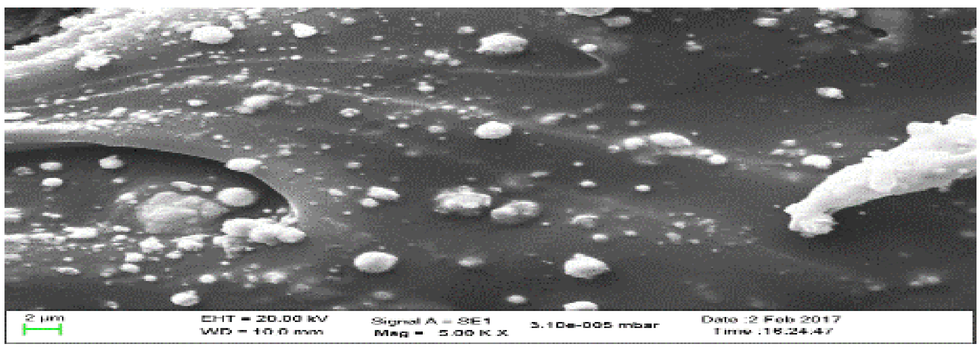
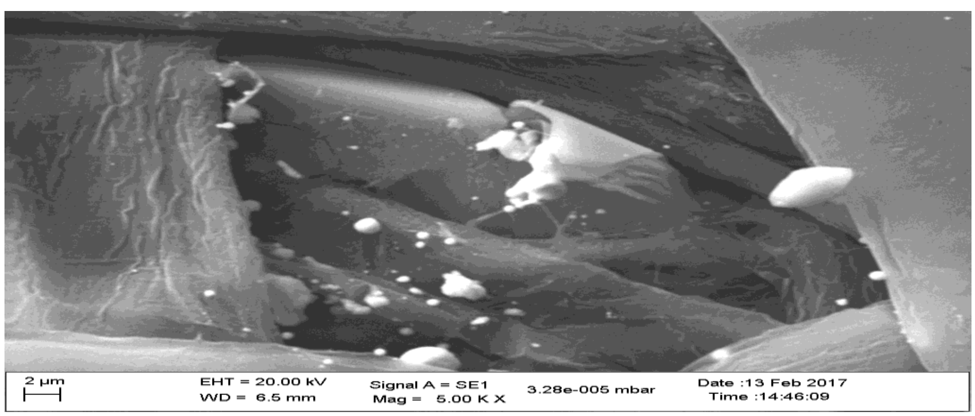
SEM was used to carried out the determination of the morphology and microstructure of GSR. EDX was done to determine the elemental composition and percentage composition of GSR. Examination of GSR Particles from 7.65mm & .315”/8mm calibre of country made and Standard firearm on paper and cloth target, using KF (Khadki factory, pune) ammunition.

It is found that, in case of 7.65 mm calibre on cloth and paper target, more number of particles of GSR observed at 4” distance, as the range increases, the no. of particles decreases. The particle size of GSR increases as the range of firing increases.

The particles of GSR at 4” distance is somewhat spherical in shape. At the distance of 8”, the particles of GSR are roughly spherical in shape.

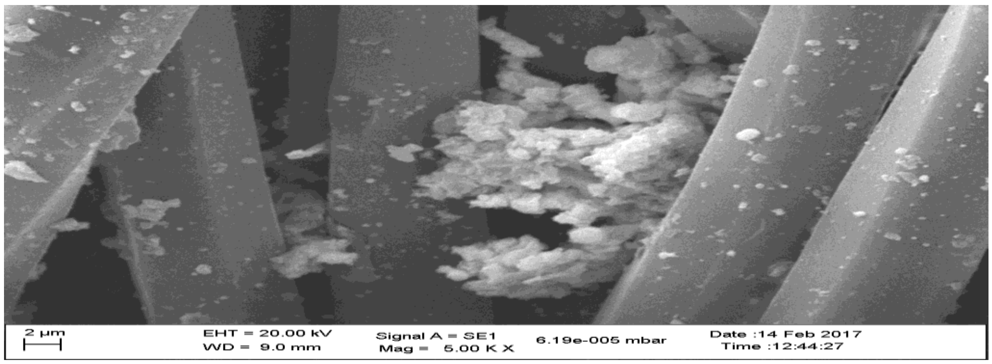
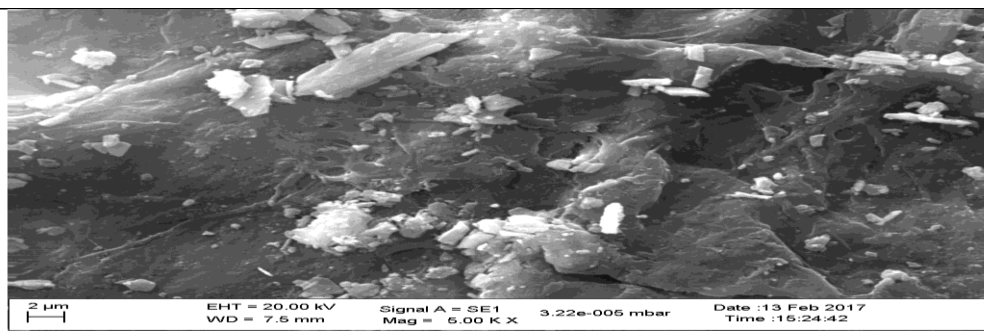
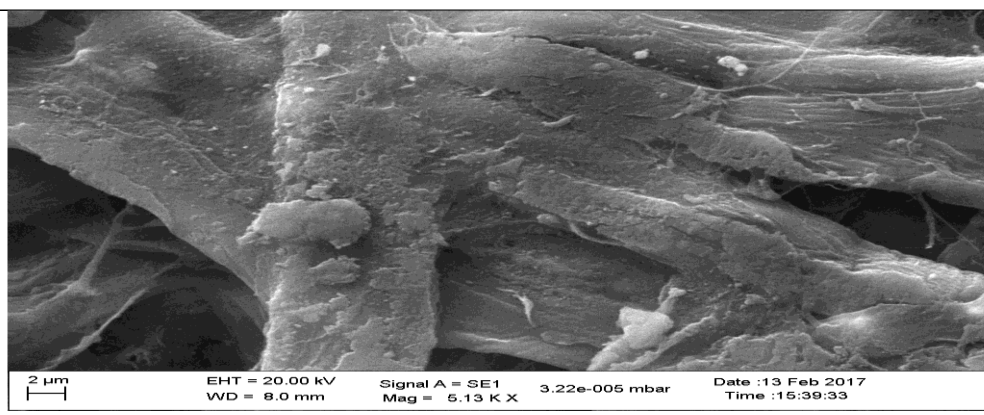
At the distance of 12”, the particles size of GSR is of irregular spherical shape. The shape of Particle size is varying in case of standard and country made firearm. The Shape of the Particles of GSR was Spherical, when fired from standard firearm. In case of country made firearms, the shape of the GSR particles is somewhat irregular.

**Fig. 4.12.1. <u>Showing the morphology of GSR on paper target fired by 7.65mm calibre of Standard firearm</u>**

| **Range** | **7.65mm calibre of standard firearm on Paper target** |
|---|---|
| |   |
| 8” |   |
| 12” |   |

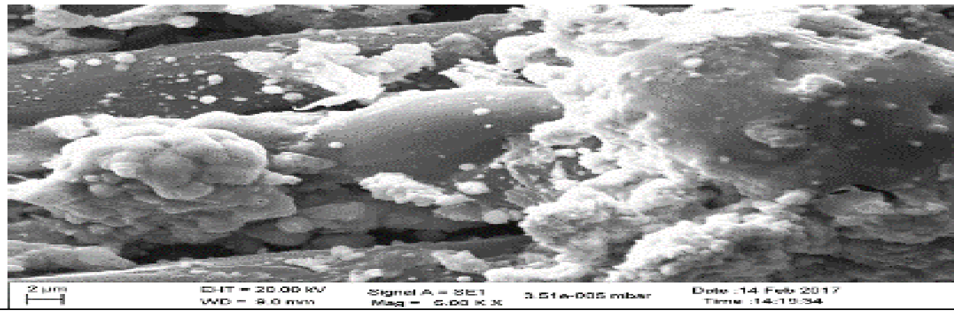
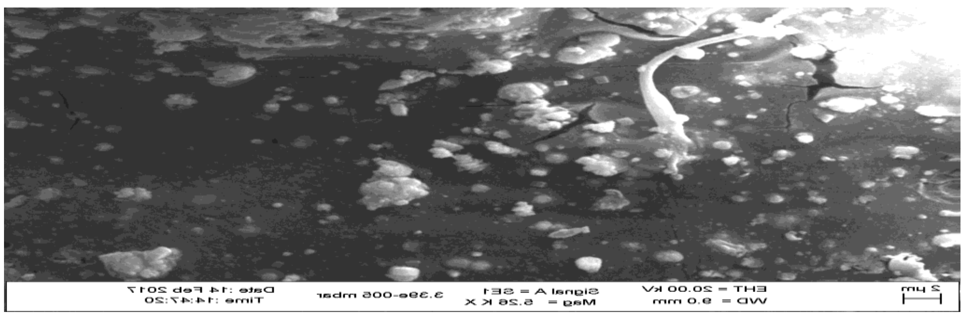
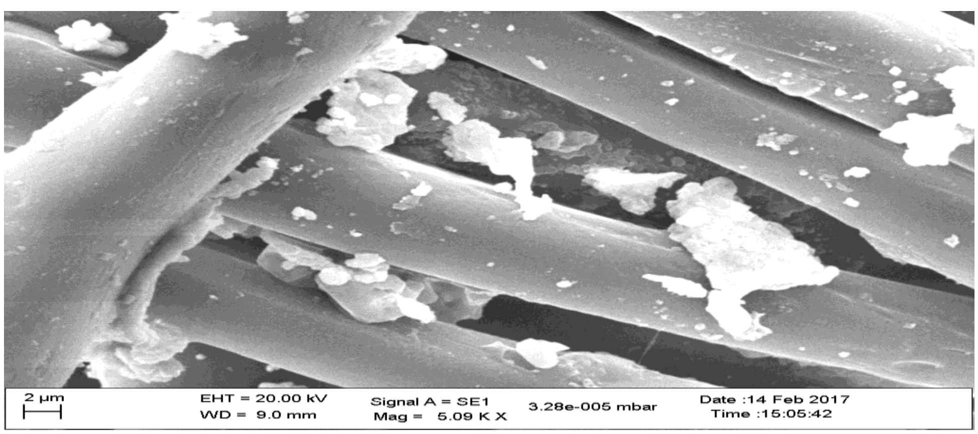
It is observed that, at 4” distance, more no. of GSR particles were observed, small in size and somewhat spherical in shape. As the range increases, the size of GSR particles increases due to clumping of GSR particles.

## Fig. 4.12.2. <u>Showing the morphology of GSR on paper target fired by 7.65mm calibre of country made firearm</u>

| Range | 7.65mm calibre of country made firearm on Paper target |
|---|---|
| 4” |   |
| 8” |   |
| 12” |   |

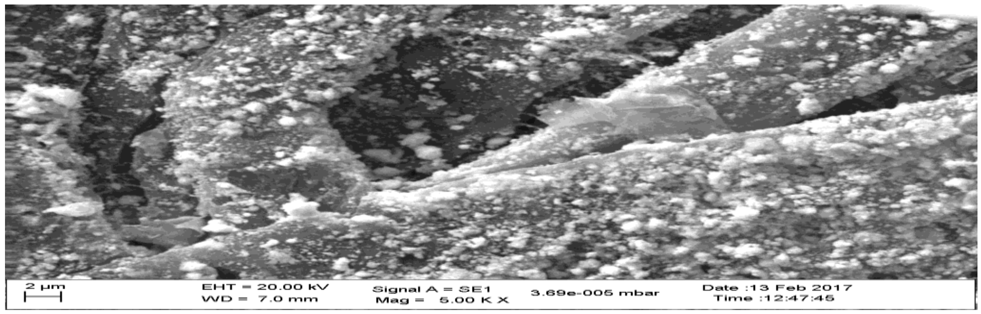
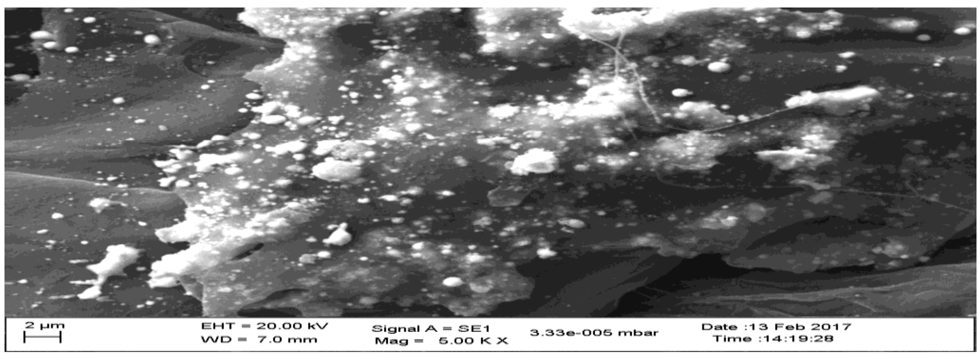
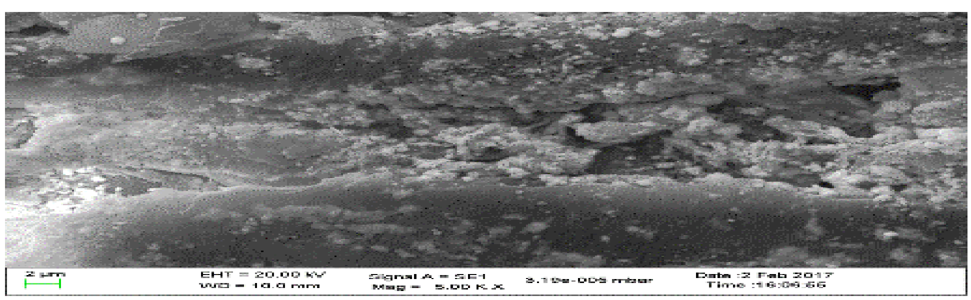
It is observed that, at 4” distance, more no. of GSR particles were observed, small and somewhat rough irregular circular in shape. As the range increases, the size of GSR particles increases due to clumping of GSR particles and becomes irregular in shape.

**Fig. 4.12.3.** **Showing the morphology of GSR on cotton cloth target fired by 7.65mm calibre of country made firearm**

| Range | 7.65mm calibre of Country made Pistol on Cotton Cloth |
|---|---|
| **4"** |  |
| **8"** |  |
| **12"** |  |

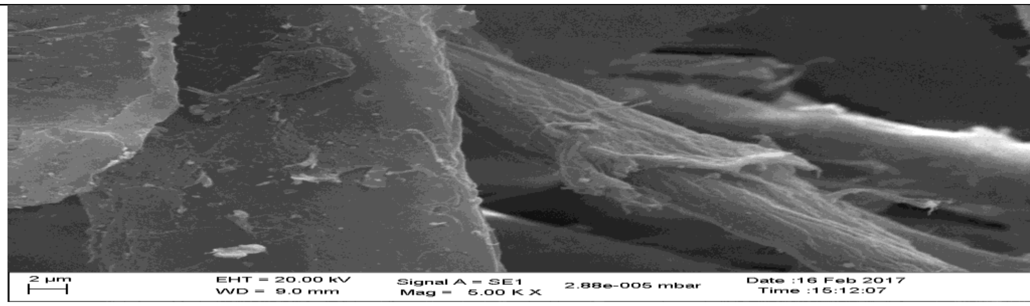
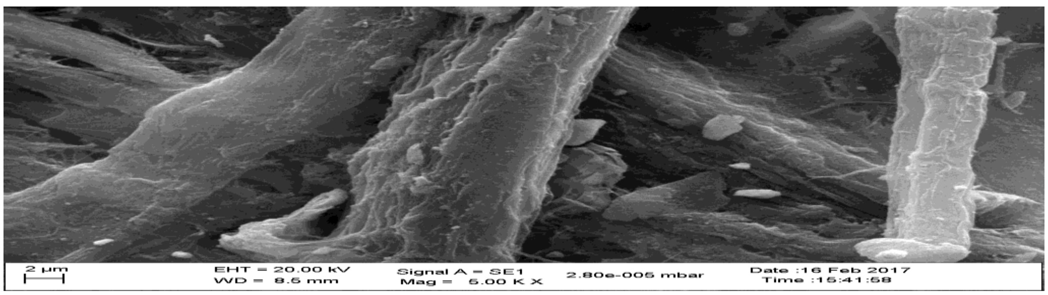
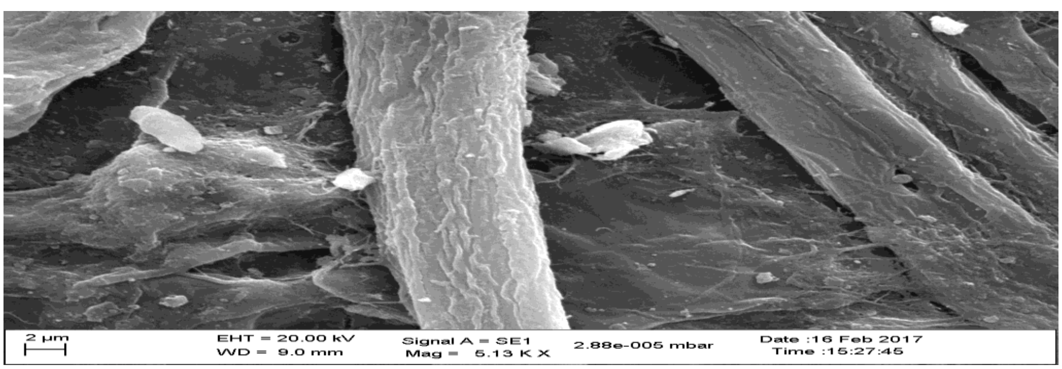
It is observed that, at 4" distance, more no. of GSR particles were observed, small in size and somewhat rough irregular circular in shape. As the range increases, the size of GSR particles increases due to clumping of GSR particles and becomes irregular in shape.

**Fig. 4.12.4. <u>Showing the morphology of GSR on cotton cloth target fired by 7.65mm calibre of Standard firearm</u>**

| Range | 7.65mm calibre of standard pistol on Cotton Cloth |
|---|---|
| **4"** |  |
| **8"** |  |
| **12”** |  |

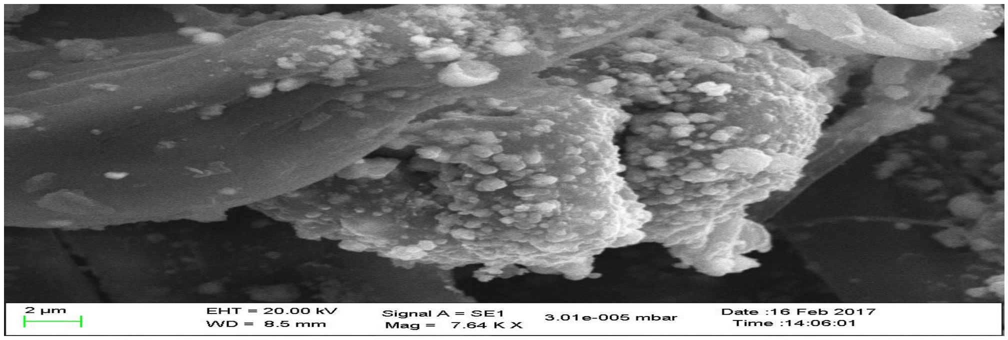
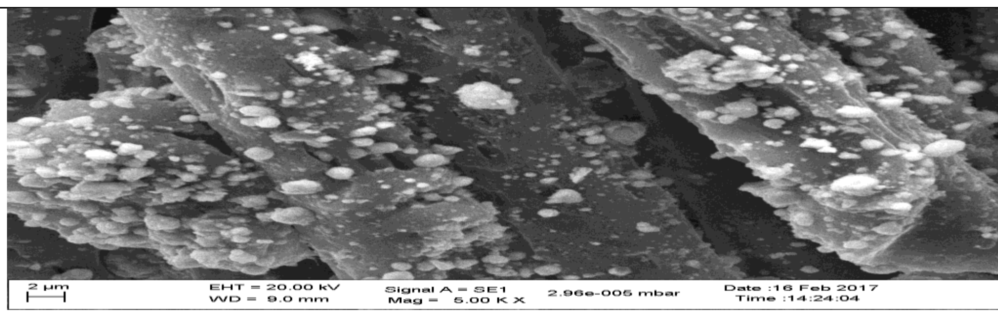
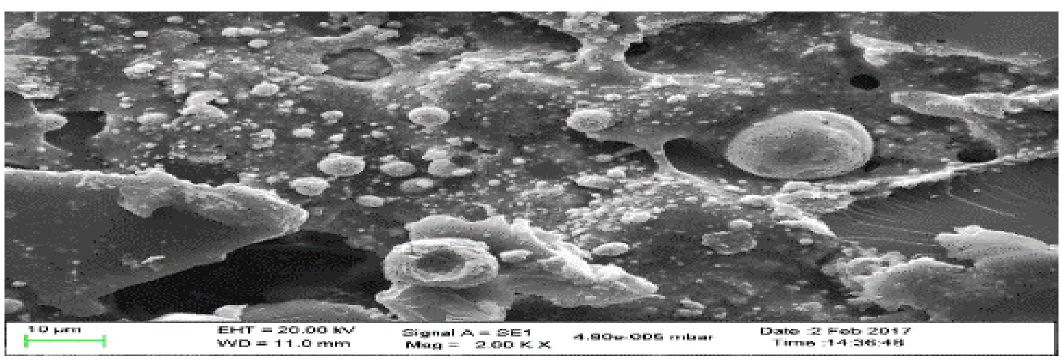
It is observed that, at 4” distance, more no. of GSR particles were observed, small in size and somewhat rough irregular circular in shape. As the range increases, the size of GSR particles increases due to clumping of GSR particles and becomes irregular in shape.

**Fig. 4.12.5. <u>Showing the morphology of GSR on paper target fired by .315”/8mm calibre of country made firearm</u>**

| Range | .315”/8mm calibre of country made firearm on Paper target |
|---|---|
| 4” |  |
| 8” |  |
| 12” |  |

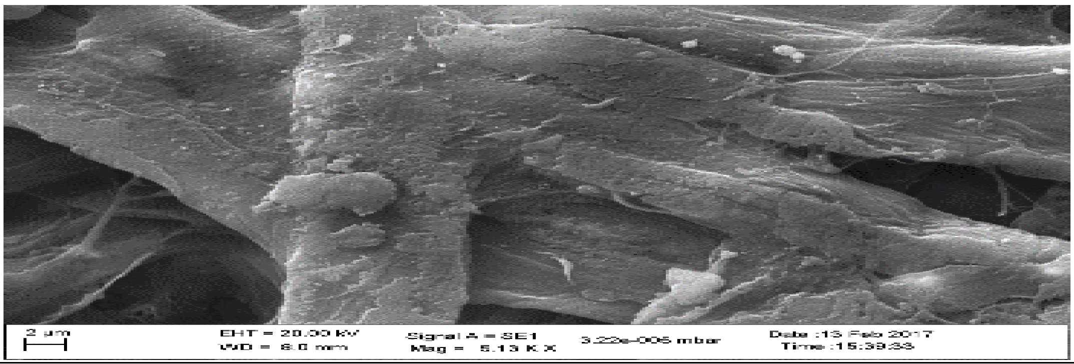
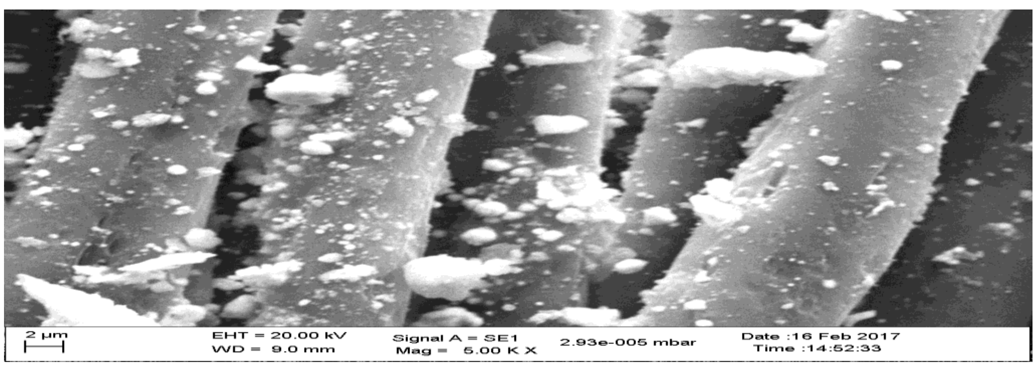
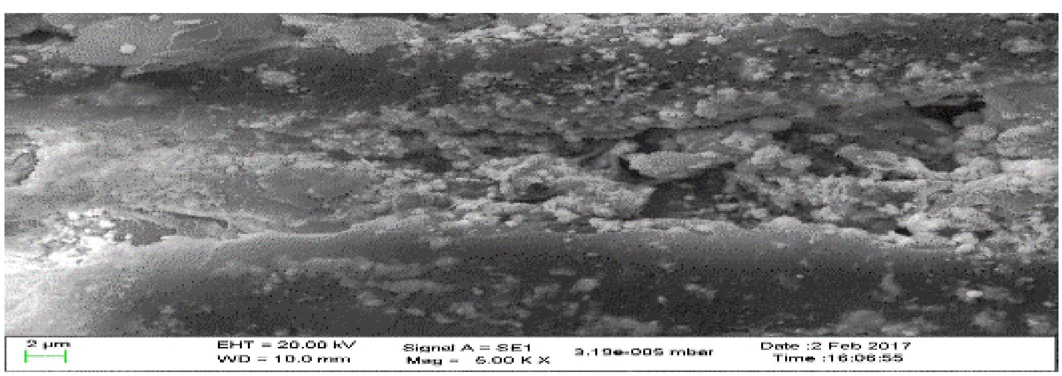
It is observed that, at up to 8” distance, very less GSR particles were observed, and at 12” distance, more GSR Particles were observed as compared to 4” and 8” distance. The shape of GSR particles is somewhat rough spherical in shape.

**Fig. 4.12.6. <u>Showing the morphology of GSR on paper target fired by.315"/8mm calibre of standard firearm</u>**

| Range | .315"/8mm calibre of standard firearm on Cloth target |
|---|---|
| **4"** |  |
| **8"** |  |
| **12"** |  |

It is observed that, at 4" distance, more clumping of GSR particles observed at one area in spherical shape because GSR particles gets less area to travel in air, so more particles deposited at one area due to which large clumping of GSR particles are observed and more target damaged were observed at close range. At 8" distance, uniform distribution of GSR particles were observed in spherical shape. At 12” distance, the size of GSR particles observed bigger in size as compared to the GSR particles fired from 8” distance, somewhat rough spherical in shape, which varies in size.

**Fig. 4.12.7. <u>Showing the morphology of GSR on Cotton cloth target fired by .315”/8mm calibre of Country made firearm</u>**

| **Range** | **.315”/8mm country made firearm on Cloth Target** |
|---|---|
| **4"** |   |
| **8"** |   |
| **12"** |   |

It is observed that, at 4” distance, no GSR particles were observed, and at 12” distance, more GSR Particles were observed as compared 8” distance. The shape of GSR particles is somewhat irregular.

## 4.13. Energy Dispersive X-rays Analysis of GSR particles

Energy Dispersive X-rays was carried out to determine the elemental composition of Gun Shot Residue. EDX analysis at different shooting distances

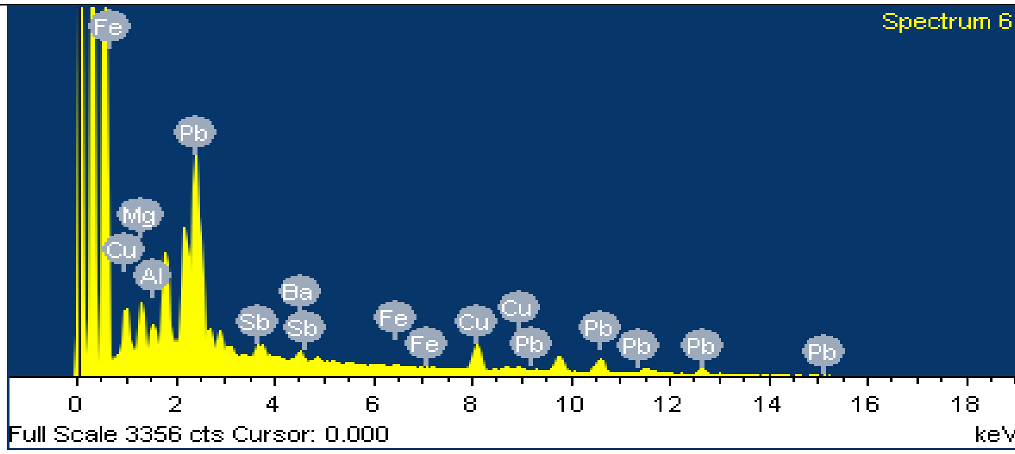
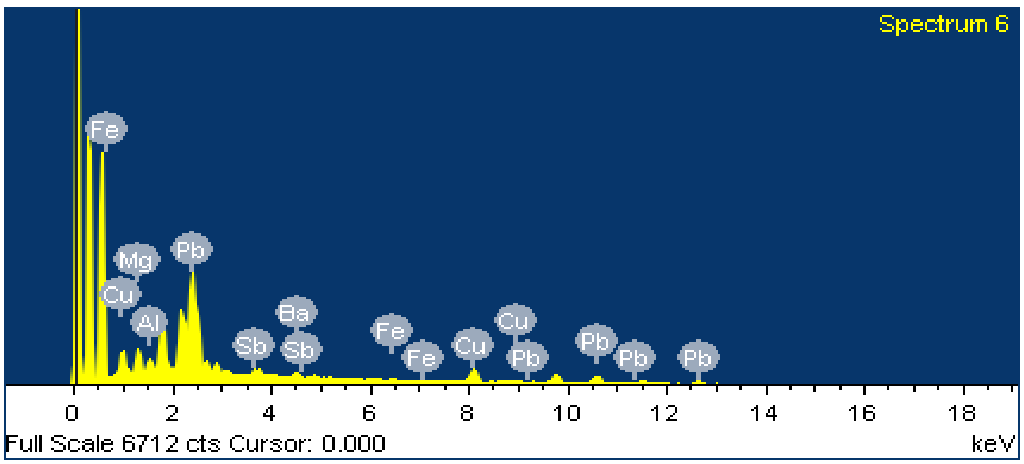
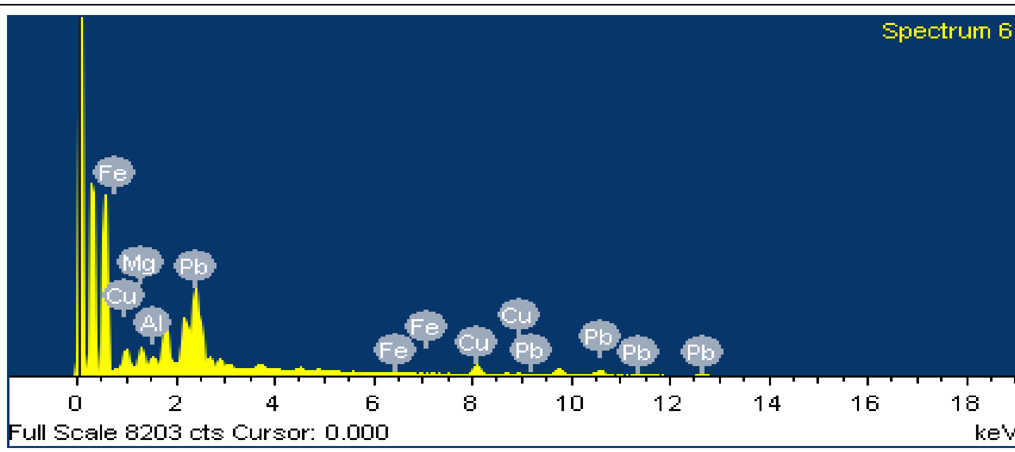
### 1. 7.65mm Calibre of Country made firearm on Paper Substrate

After test firing from three different ranges i.e., 4", 8" and 12" from 7.65mm calibre of country made pistol on paper substrate. It is found that most important GSR Particles Pb, Ba and Sb are found up to 8" range of firing. But at 12" range of firing, Ba and Sb was absent, Pb was present. Fe, Cu and Mg are present upto 12" range, but we cannot consider these elements as an important constituent particle of GSR because Fe and Cu may be come from the barrel of gun and from the scrapping of cartridge case. Pb, Ba and Sb are considered as an important GSR components because they are originate from the primer and propellant. In modern cartridges, the main composition of primer is mercury fulminate, Lead azide, Lead Styphante.

**Table 4.13.1. Showing all the GSR elements present at different range**

| Range | GSR particles present |
|---|---|
| 4" | Fe, Cu, Mg, Al, Pb, Sb, Ba |
| 8" | Fe, Cu, Mg, Pb, Ba, Sb |
| 12" | Fe, Cu, Mg, Al, Pb |

**Fig. 4.13.1 (a). Showing EDX spectrum and elemental composition of GSR fired from 7.65mm calibre of country made pistol on Paper Substrate**

| RANGE | EDX Spectrum and elemental composition of GSR |
|---|---|
| 4” |  |
| 8" |  |
| 12” |  |

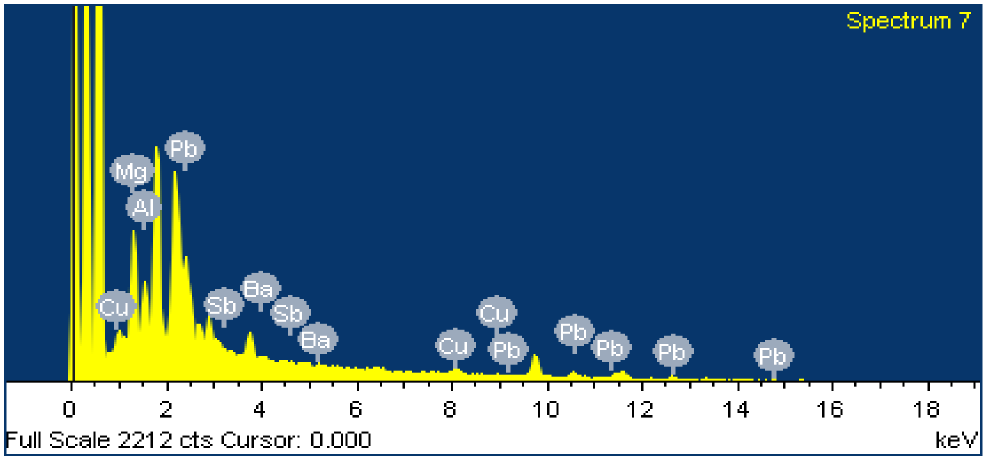
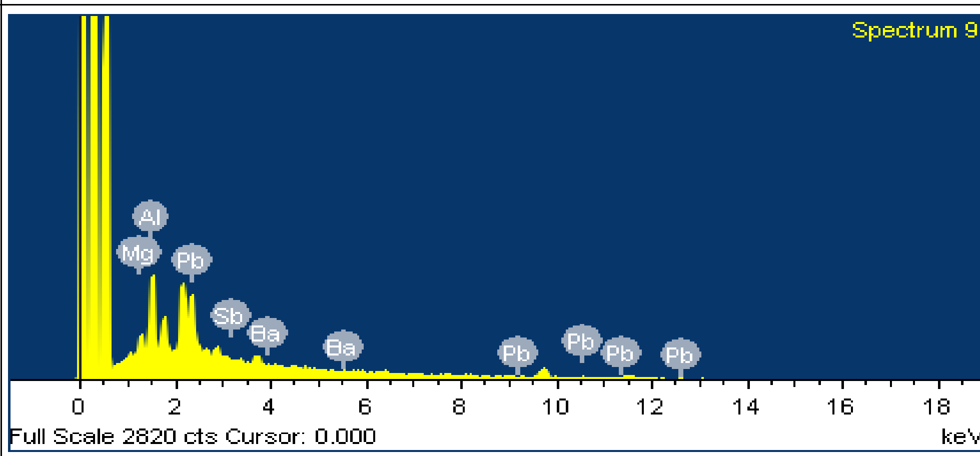
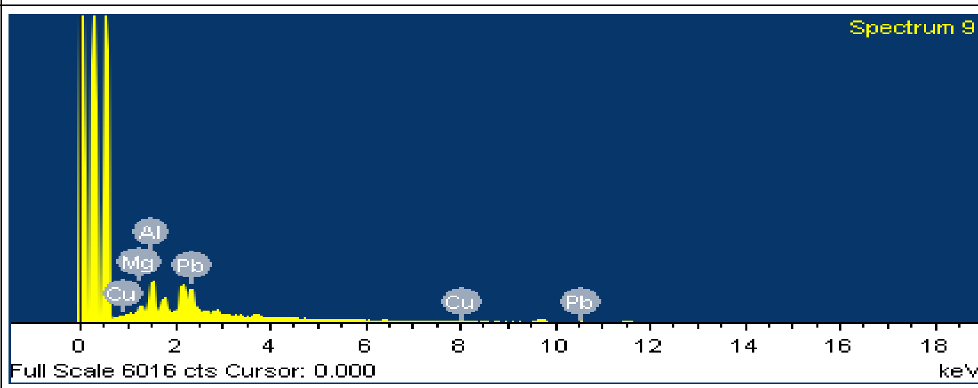
## 2. 7.65mm Calibre of country made firearm on cloth Substrate

It is found that most important GSR Particles Pb,Ba, Sb were found up to 8" range of firing. But at 12" range of firing, Ba and Sb was absent, Pb was present.

**Table 4.13.2. Showing all the GSR elements present at different range**

| Range | GSR particles present |
|---|---|
| **4"** | Cu, Mg, Al, Pb, Sb, Ba |
| **8"** | Al, Cu, Mg, Pb, Ba, Sb |
| **12"** | Al, Cu, Pb, Mg |

**Fig. 4.13.2. (a)__Showing EDX spectrum and elemental contribution of GSR fired from 7.65mm calibre of country made on cloth Substrate__**

| RANGE | EDX Spectrum and elemental contribution of GSR |
|---|---|
| 4” |  |
| 8” |  |
| 12” |  |

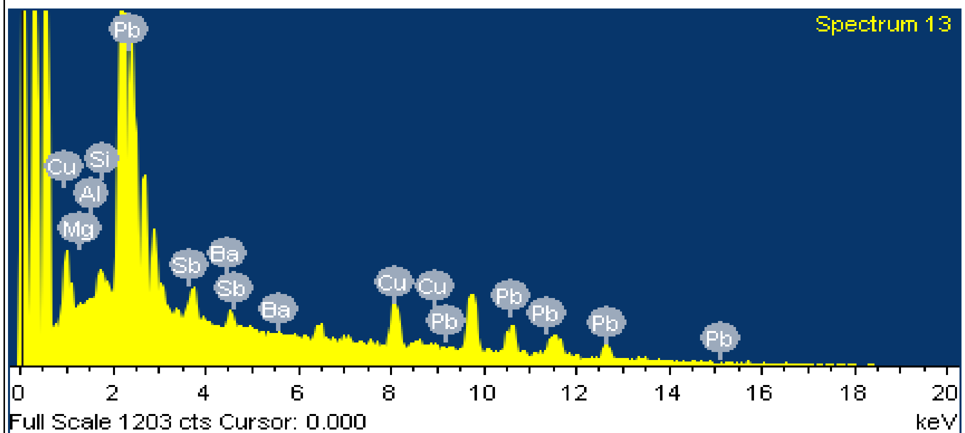
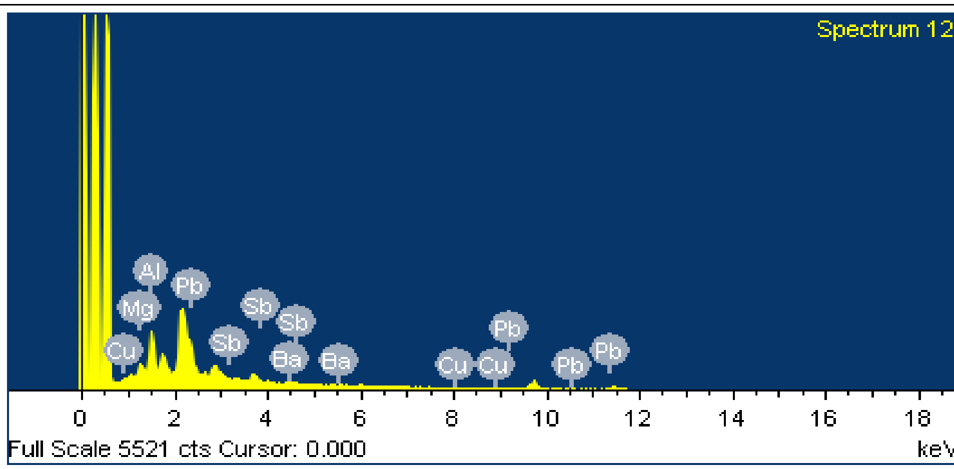
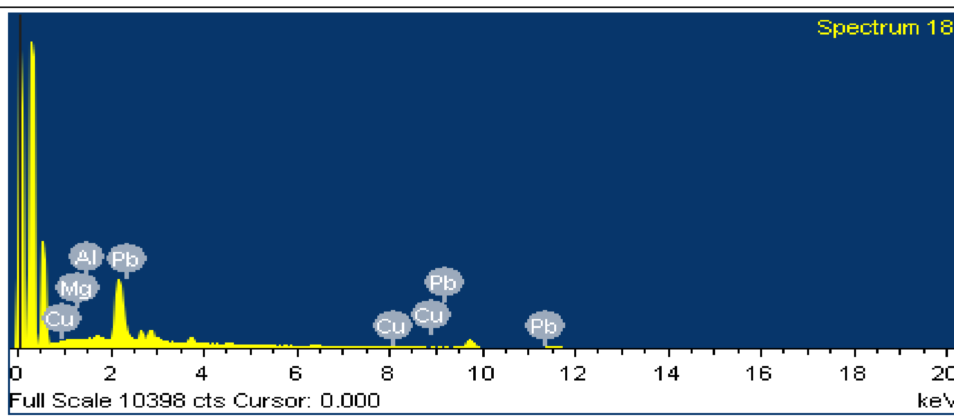
3. **<u>7.65mm Calibre of Standard firearm on paper Substrate</u>**

It is found that most important GSR Particles Pb,Ba,Sb were found up to 8" range of firing. But at 12" range of firing, Ba and Sb was absent, Pb was present.

**Table 4.13.3. Showing all the GSR elements present at different range**

| Range | GSR particles present |
|---|---|
| **4"** | Cu, Mg, Al, Pb, Sb, Ba, Si |
| **8"** | Al, Cu, Mg, Pb, Ba, Sb |
| **12"** | Cu, Mg, Al, Pb |

**Fig. 4.13.3 (a). Showing EDX spectrum and elemental contribution of GSR fired from 7.65mm calibre of Standard firearm on Paper Substrate**

| RANGE | EDX Spectrum and elemental contribution of GSR |
|---|---|
| 4" |   |
| 8" |   |
| 12" |   |

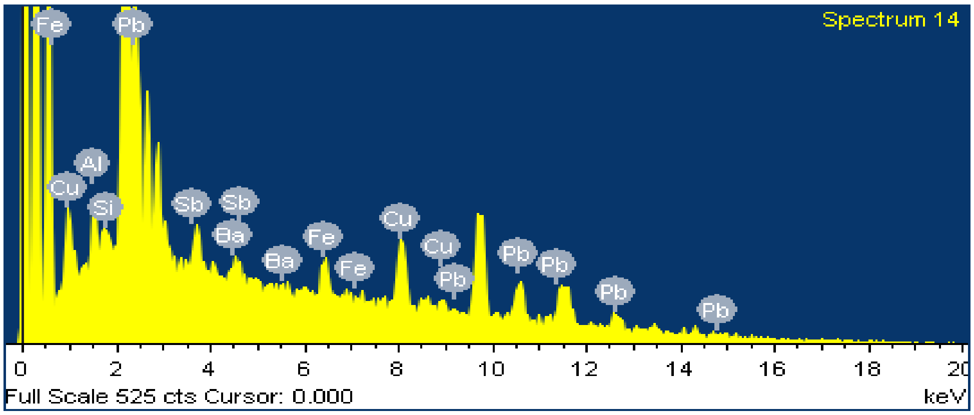
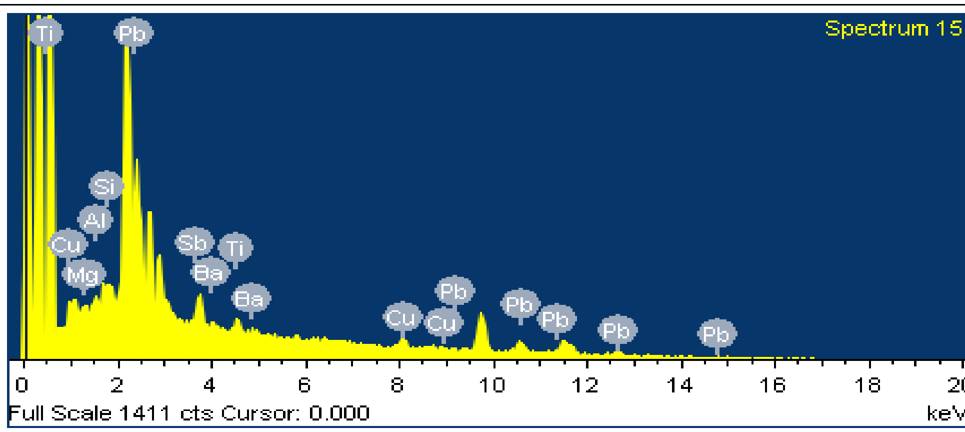
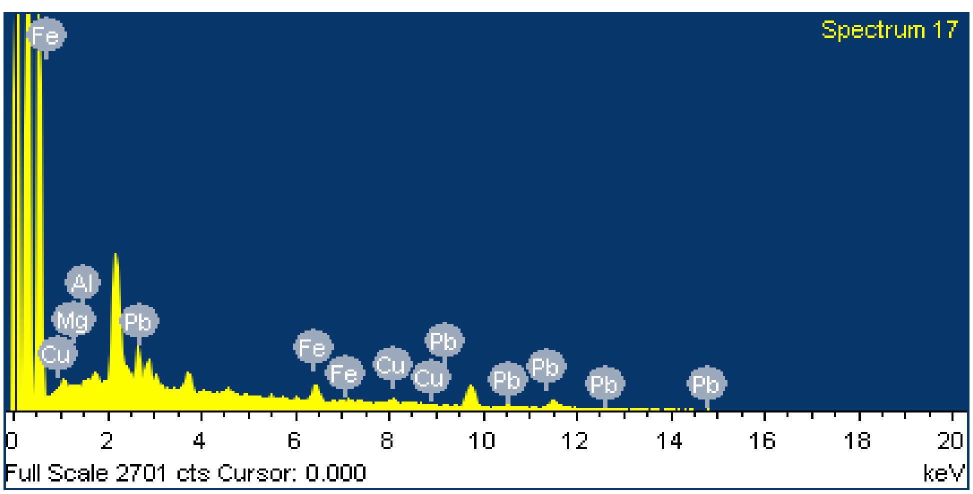
## 4.7.65mm Calibre of standard on Cotton Cloth Substrate

It is found that most important GSR Particles Pb,Ba,Sb were found up to 8" range of firing. But at 12" range of firing, Ba and Sb was absent, Pb was present.

**Table 4.13.4. Showing all the GSR elements present at different range**

| Range | GSR particles present |
|---|---|
| **4"** | Cu, Mg, Al, Pb, Sb, Ba, Si |
| **8"** | Al, Cu, Mg, Pb, Ba, Sb |
| **12"** | Cu, Mg, Al, Pb |

**Fig. 4.13.4 (a_). <u>Showing EDX spectrum and elemental contribution of GSR fired from 7.65mm calibre of Standard firearm on Cotton Cloth Substrate</u>**

<table>
<tr><th>RANGE</th><th>EDX Spectrum and elemental contribution of GSR</th></tr>
<tr><td>4"</td><td>
</td></tr>
<tr><td>8"</td><td>
</td></tr>
<tr><td>12"</td><td>
</td></tr>
</table>

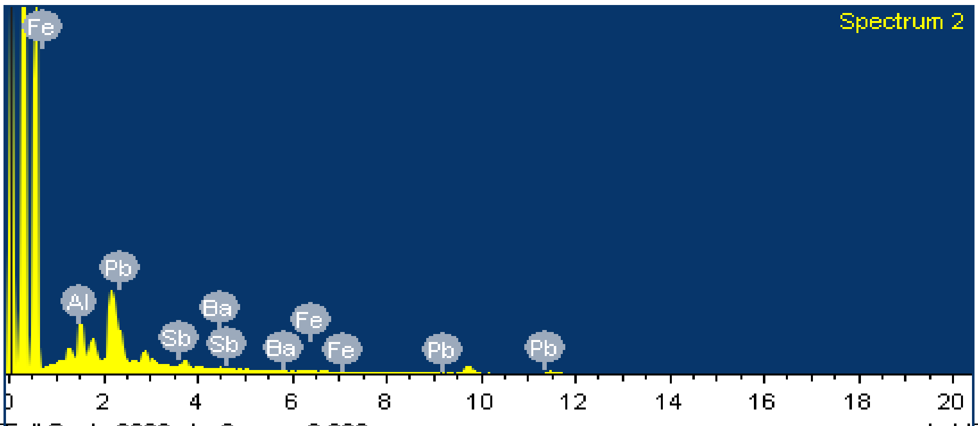
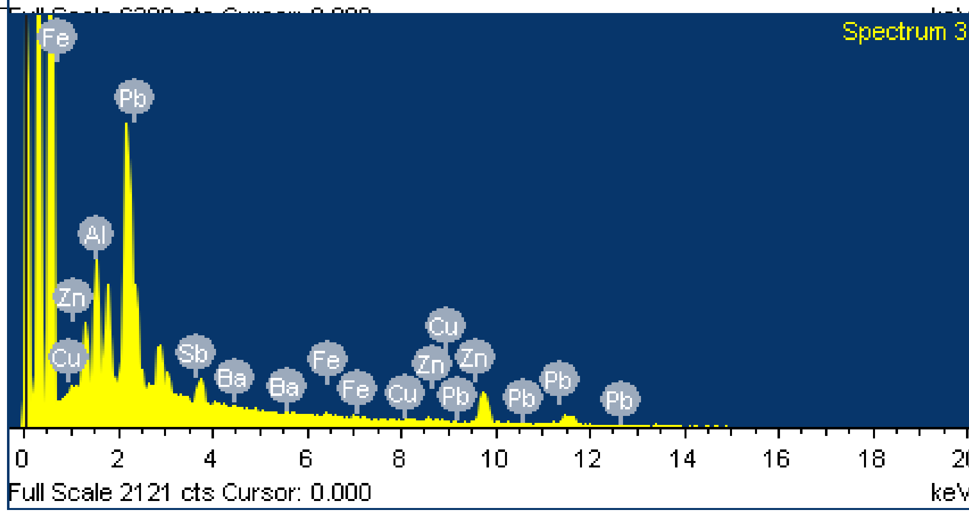
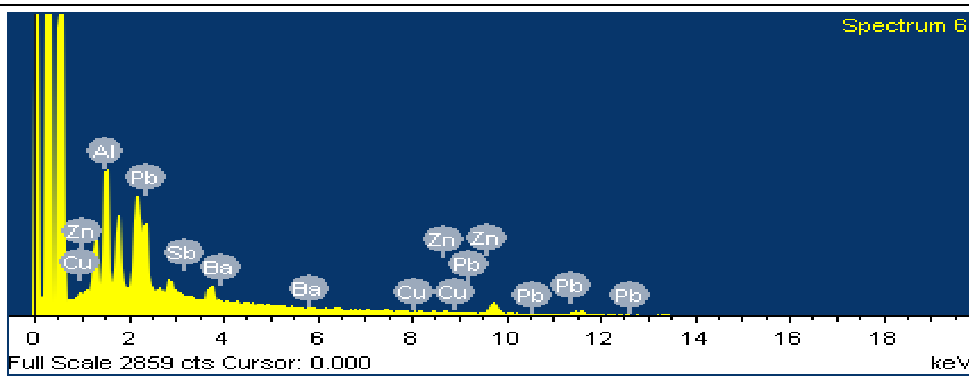
## 5. <u>0.315"/8mm Calibre of Country made firearm on Paper Substrate</u>

It is found that most important GSR Particles Pb, Ba,Sb were found up to 12" range of firing.

**Table.4.13.5. <u>Showing all the GSR elements present at different range</u>**

| Range | GSR particles present |
|---|---|
| **4"** | Al, Fe, Pb, Sb, Ba |
| **8"** | Fe, Cu, Zn, Al, Pb, Sb,Ba |
| **12"** | Cu, Zn, Al, Pb, Sb, Ba |

**Fig. 4.13.5 (a). <u>Showing EDX spectrum and elemental contribution of GSR fired from 0.315"/8mm calibre of Country made firearm on Paper Substrate</u>**

| **RANGE** | EDX Spectrum and elemental contribution of GSR |
|---|---|
| 4" |  |
| 8" |  |
| 12" |  |

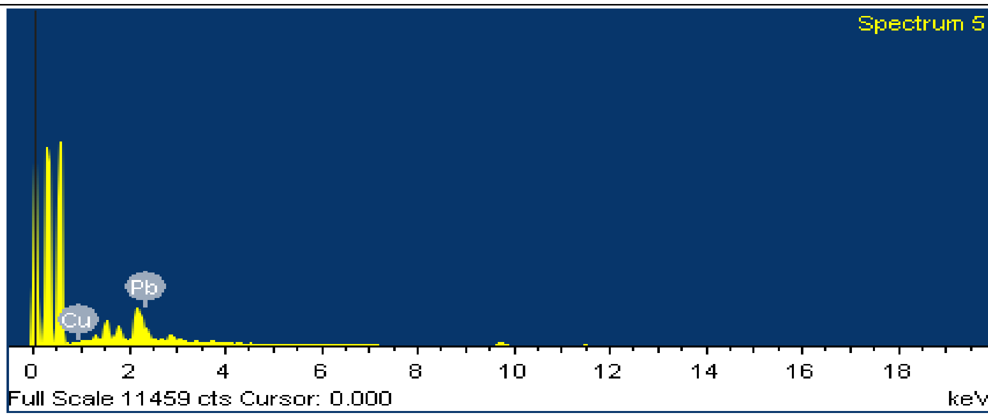
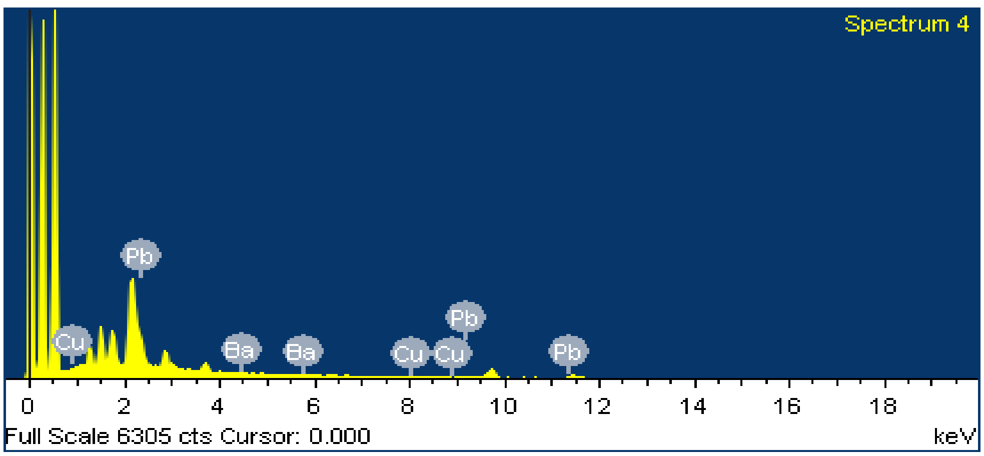
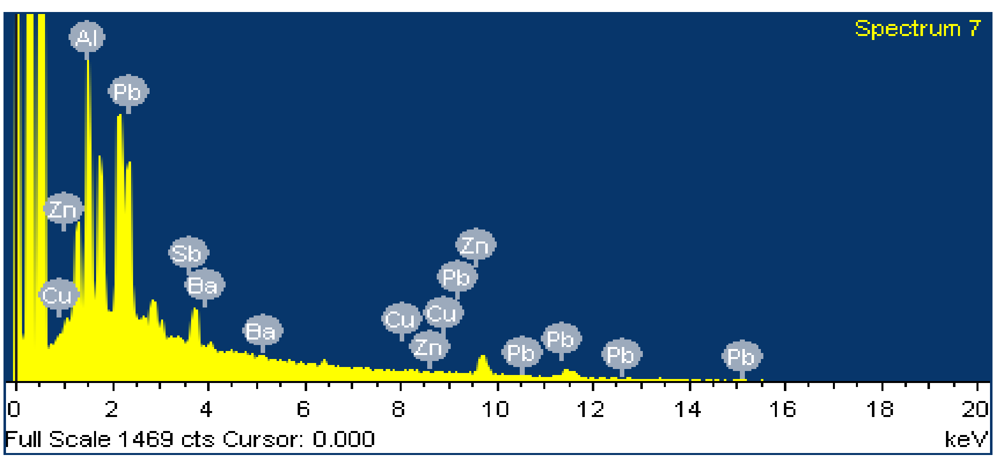
## 6. 0.315"/8mm Calibre of standard firearm on Paper Substrate

It is found that most important GSR Particles Pb,Ba,Sb were found up to 12" range of firing.

**Fig.4.13.6. Showing all the GSR elements present at different range**

| Range | GSR particles present |
|---|---|
| **4"** | Cu, Pb |
| **8"** | Cu, Pb, Ba |
| **12"** | Cu, Zn, Al, Pb, Sb, Ba |

**Fig. 4.13.6(a). Showing EDX spectrum and elemental contribution of GSR fired from 0.315"/8mm calibre of standard firearm on Paper Substrate**

| RANGE | EDX Spectrum and elemental contribution of GSR |
|---|---|
| 4" |  |
| 8" |  |
| 12" |  |

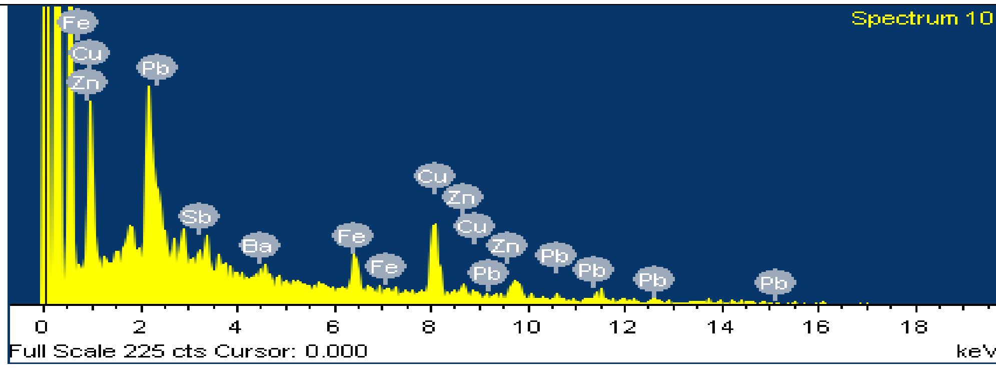
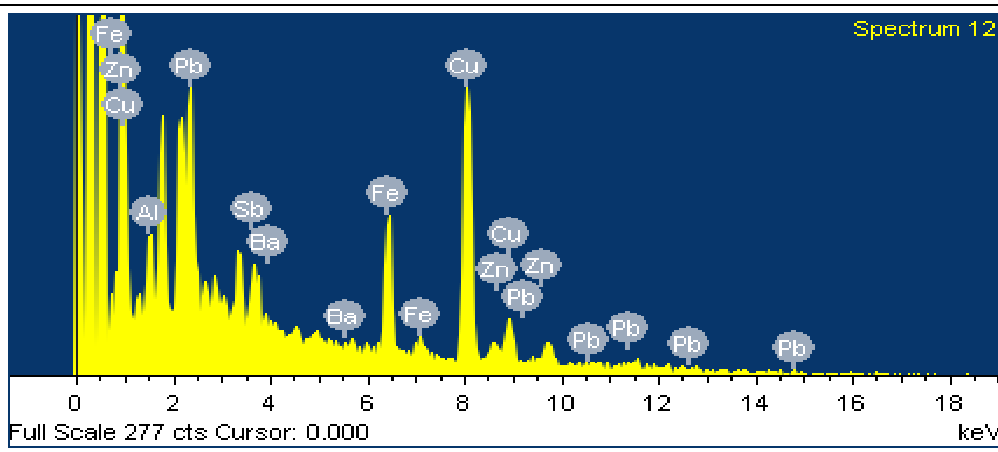
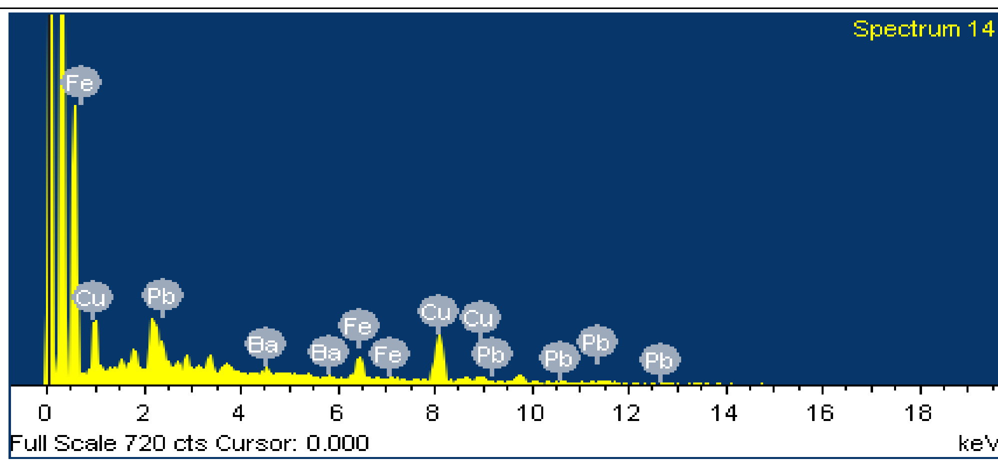
**7. 0.315"/8mm calibre of Country made firearm on Cotton Cloth Substrate.**

It is found that most important GSR Particles Pb, Ba, Sb were found up to 12" range of firing.

**Fig.4.13.7. Showing all the GSR elements present at different range**

| **Range** | **GSR particles present** |
|---|---|
| **4"** | Cu, Pb |
| **8"** | Cu, Pb, Ba |
| **12"** | Cu, Zn, Al, Pb, Sb, Ba |

**Fig.4.13.7(a). Showing EDX spectrum and elemental contribution of GSR fired from .315”/8mm calibre of Country made firearm on Cotton Cloth Substrate**

<table>
<tr><th>RANGE</th><th>EDX Spectrum and Elemental contribution of GSR</th></tr>
<tr><td>4"</td><td>
</td></tr>
<tr><td>8"</td><td>
</td></tr>
<tr><td>12"</td><td>
</td></tr>
</table>

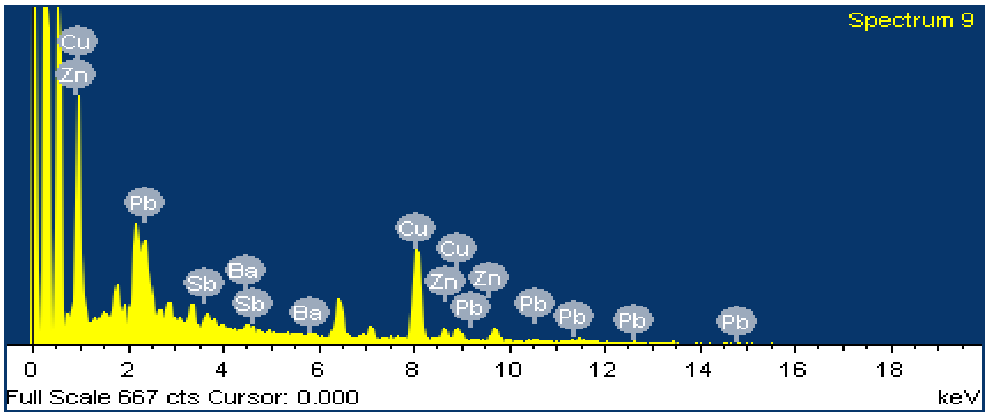
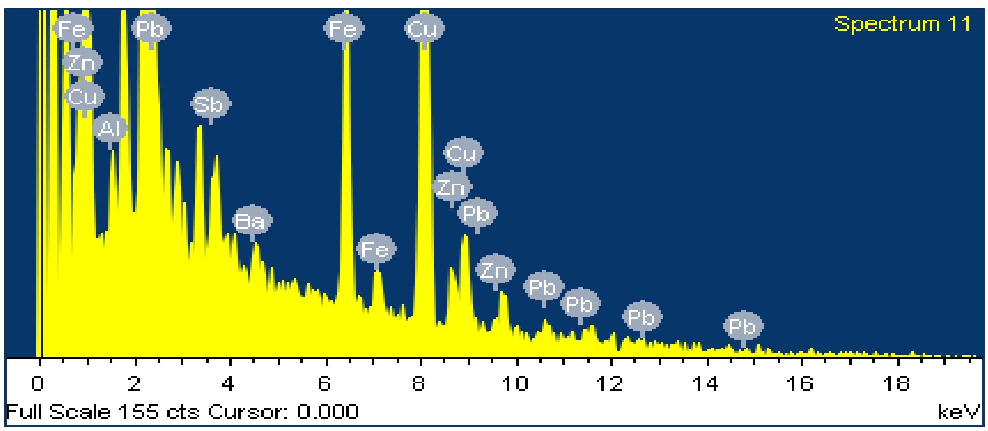
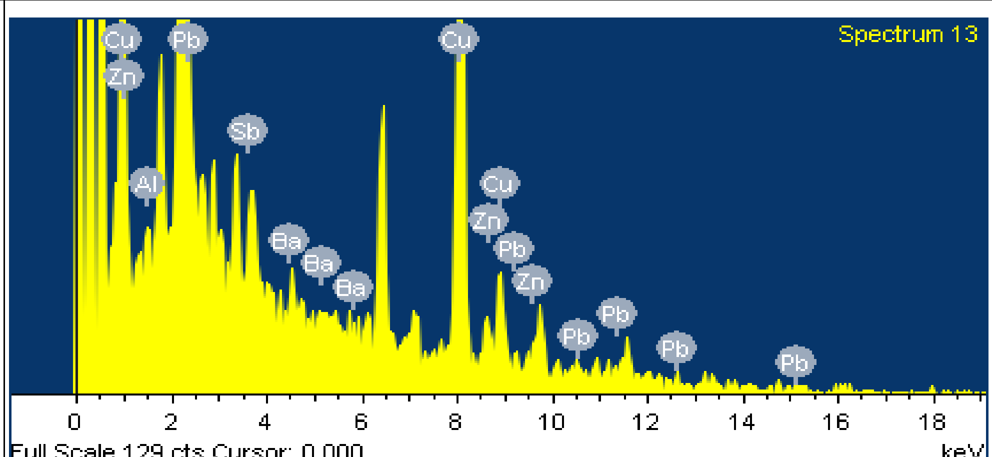
## 8. **0.315”/8mm calibre of standard firearm on Cotton Cloth Substrate**.

It is found that most important GSR Particles Pb, Ba, Sb were found up to 12" range of firing.

**Table. 4.13.8. Showing all the GSR elements present at different range**

| Range | GSR particles present |
|---|---|
| **4"** | Cu, Zn, Pb, Sb, Ba |
| **8"** | Zn, Cu, Al, Pb, Sb, Ba |
| **12"** | Cu, Zn, Al, Pb, Sb, Ba |

**Fig.4.13.8(a)Showing EDX spectrum and elemental contribution of GSR fired from .315”/8mm calibre of standard firearm on Cotton Cloth Substrate.**

<table>
<tr><th>RANGE</th><th>EDX Spectrum and Elemental contribution of GSR</th></tr>
<tr><td>4”</td><td>
</td></tr>
<tr><td>8”</td><td>
</td></tr>
<tr><td>12”</td><td>
</td></tr>
</table>

# CHAPTER 5

# CONCLUSION

In this thesis, we demonstrate the methods for determination of muzzle-to-target distance, determination of calibre used, determination of type of weapon, whether firing was done through countrymade firearm or standard firearm, based on dispersion pattern of Gun Shot Residue, by morphology of GSR through scanning electron microscope and the detection of elemental composition through Energy dispersive X-ray detector. A database is prepared through this study, this database is helpful in determing the range of firearm of country made and standard firearm. This study is more helpful specially for country made firearms of calibre 7.65mm and .315"/8mm in close range upto 30cm.

Examination of Gun shot residue is very important factor in field of forensic ballistics and in the similar way determination of range of firing of country made firearm is also very important as trend of country made firearm is increasing day by day in india and its quite very difficult for estimation of range of firing especially in case of countrymade firearm.

There is always controversery in case of countrymade firearms, what is the exact range of firearm, whether the injury caused by countrymade or standardfirearm.

This study was carried out on close range uotp 12" distance, as GSR is more deposited in close range, as the range increases the GSR partices are spread in the the air, as GSR particles are very light in weight. So, its dificult to analyse GSR particles in case of distance firing.

The test firing was done from three distances i.e.4", 8" and 12" from two caibre 7.65mm and.315"/mm from standard and country made firearms on cotton cloth and paper substrate. The result of this research was concluded by three important analysis. Firstly, the dispersion pattern area of GSR was calculated by using the formula of area of circle ana a database is prepared from all the three close range of both caliber of standard and countrymade firearm on two different substrate. This data will be helful in the estimation of range from three parameters i.e, caliber, type of firearm and substrate (i.e cotton cloth and chart paper). From the database, it concluded that more disperion of GSR is seen in case of close range and the dispersion area reduces with increasing range and the value of disperion pattern will help in exact estimation of range upto 30cm distance, in both caliber of standard and countrymade firearms on cotton cloth and paper sustrate.

In the second step of analysis, The GSR sample was collected from the target surface and then analyzed under scanning electron microscope to find out the morphology of GSRfired from both the caliber of standard and countrymade on cotton cloth and paper substrate. Morphology of GSR showed that, Sperical form of GSR found in case of standard firearm, and irregular shape of GSR observed in case countrymade firearms due to clumping of GSR particles. Result of this study showed that, by analyse the morphology of GSR, one can find whether countrymade firearm or standard firearm used in crime.

In the third step of analysis, The GSR sample was run under Energy dispersive X-Ray detector, for the determination of elements present in different close range from different caliber and on different substrate fired from both countrymade and standard firearm. Variation have been observed from different close range and more variations are observed , when firing done from country made firearmfrom these two calibres of country made and Standard Firearms i.e. 7.65mm & .315”/8mm and anmmunition on different Substrate. This study will help the forensic exerts to dispose off the cases, where range of firing is to ascertain when countrymade firearm were used in the crime.

## FUTURE WORK

Future work with this research work is very much needed. This study was done on two calibers , two substrate and from the 3 close ranges (i.e. 4”,8” & 12”) . This work can be performed with other different weapons of different calibre, different substrate and more ranges. Once the database of more and more firearms is prepared with more ranges and on different different substrate. This work carry more potential. Once the database of all the firearms is prepared, it will help in more and more disposal of the cases and help the investigators to find the truth behind the case.

# CHAPTER 6

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