

Determination of firing range of firearm by Dispersion pattern of GSR

Komal Yadav¹, Prashant Agrawal², NB Bardhan³, AK Jain⁴

Abstract

Gun Shot residue plays a very important role in forensics ballistics cases and the dispersion of GSR particles helps in the estimation of range of firing. Gun shot residue particles are found in close range because of light weight particles, they spread in air, when firing was done from long distance. Therefore GSR plays a very crucial role in solving the cases, when firing was done from the close range. The aim of this study is to determine the shooting distance and firearm fired from close range i.e. 4", 8" and 12". This study consists of two types of firearm 7.65mm amd.315"/8mm caiber of countrymade pistol. The samples were collected from the ballistics division of CFSL/CBI/New Delhi on cotton cloth target. The ammunition and firearms were used in this study were received in the cases of ballistics division/CFSL/CBI/New Delhi. Total 180 samples were collected. The samples were analysed under three steps: Visual examination, SEM analysis and EDX analysis. The samples were analyzed under SEM/EDX at IARI, pusa road, Delhi. The result of this study shows, difference in dispersion pattern of GSR, morphology of GSR and elemental composition of GSR. This research study may be helpful in forensic examination of firearm cases.

Keywords: GSR, Dispersion pattern, Caliber, Countrymade firearm

Introduction

Firearms use has been dated back in fourteenth century but the first firearm was not much of a firearm when compared with the modern systems¹. 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 follows²:

- 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)

Firearms can be classified into three main types: Smooth bore firearms, Rifled bore firearm, Country-made firearm. Smooth bore

firearm are those, whose internal barrel is completely smooth from inside¹. They are designed to fire pellets, lead balls, and sometimes projectile.

Rifled firearms are having rifling marks (Lands and grooves) inside their barrel, which provide gyratory motion to the projectile and effects the stability of the bullet.

Countrymade firearms are also known as zip gun, desi-katta, home-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 calibers³. Due to the ease and inexpensive availability, these weapons are favourite choice for the criminals. In India 2014-2017, firearms

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were used in 12% of murders, 18% of attempted murders and 7% of robbery offences⁴.

The trend of country made firearms are increasing so fast and its difficult to determine the range of firing, where country made firearms are used. In this study, Author tried to find out the range of firing fired by countrymade firearm by dispersion pattern of GSR.

GSR is also known as FDR(Firearm discharge residue), CDR (Cartridge Discharge 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 nitrogen⁶. 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. Moreover, Gun Shot Residue can be used to differentiate weather, the firing done from close range and a distant range⁷. This may be done by the analysis of the powder pattern present on the target, and comparison to test firings.

The presence of Gun Shot Residue around a entry hole at a crime scene can be used to identify them as bullet holes.⁸ This study is performed into three main steps: One, Author calculate the dispersion pattern area from all three distances of close range firing from both the caliber of firearm and prepare a database from all the distances. This database will help in determing from which range firing was done and also determine the type of calibre.

Secondly, The samples were analysed under scanning electron microscope for the study of morphology of GSR. This will help in determing, whether the GSR particles fired from country made or standard firearm.

Thirdly, The sample were run under Energy dispersive X-Ray detector (EDX), to detect the elemental composition of GSR.

Firearms are used in a wide variety of crimes, including assault, armed robbery & murder⁵. 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 can not 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

Materials and Methods

This research work has been conducted at Central Forensic Science Laboratory, CBI, New Delhi. 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 firearms are used for shooting test. The ammunition was used of KF (Khadki Factory, Pune). In order to perform the chemical tests, Beaker, Test tube, Spray bottl, Filter paper and cotton swab were used. A canon digital camera D60 was used to photographed the GSR image.

SAMPLE SIZE

Two types of .315"/8mm and 7.65mm calibre of country made pistol were used for test firing. The ammunition of KF(khadki factory), pune were used for test firing. Total 180 samples were collected from .315"/8mm and 7.65mm calibre of both country made firearm on cotton cloth substrate from different ranges i.e. 4", 8" and 12". Thirty (30) times firing was done from the same distance with different firearms.

Country-made Firearm

One hundred and Eighty (180), country-made firearms of 7.65 mm and .315"/8mm were used for firing on the target cotton cloth substrate. These firearms were obtained from the cases received in the Central Forensic Science Laboratory, CBI (New Delhi). Ninety (90) samples were collected from 7.65mm country made pistols on cotton cloth substrate from different ranges i.e. 4", 8" and 12". Ninety (90) samples were collected from .315"/8mm country made pistol on cotton cloth substrate from different ranges i.e. 4", 8" and 12".

Cartridges

180 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 were fired from three ranges of 10 cm, 20 cm and 30 cm on the target.

Cloth

Cotton cloth of white colour was used which firing is done in criminal cases well which help in a better vision and study of dispersion pattern around the bullet hole. The dimension of each cloth sample was taken as 32 x 35 cm.



Fig.1 Cotton cloth sample

Bullet Recovery Box and Firearm Mount

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 is a 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 are carried out safely and also the bullet can be recovered from it. The firearm is 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.

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 country made pistol. The KF ammunition 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 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', 12" on the target from each of 7.65mm and .315"/8mm country made firearms. Thereafter GSR pattern on the 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.

SHOOTING TEST

The purpose of the Firing test was to determine the range of firing from muzzle end to the target. The distances were choosen 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 by 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 was used for analysis of morphology of GSR Particles.



Fig. 2. Firing range, site of sample collection at CFSL/CBI/NEW Delhi

INSTRUMENT USED

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.

Result and Discussion

Visual Examination

The determination of firing distance was first observed on the basis visual examination on the cotton cloth target at different distance fired by different calibre country made firearms. The dispersion pattern was somewhat 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 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:

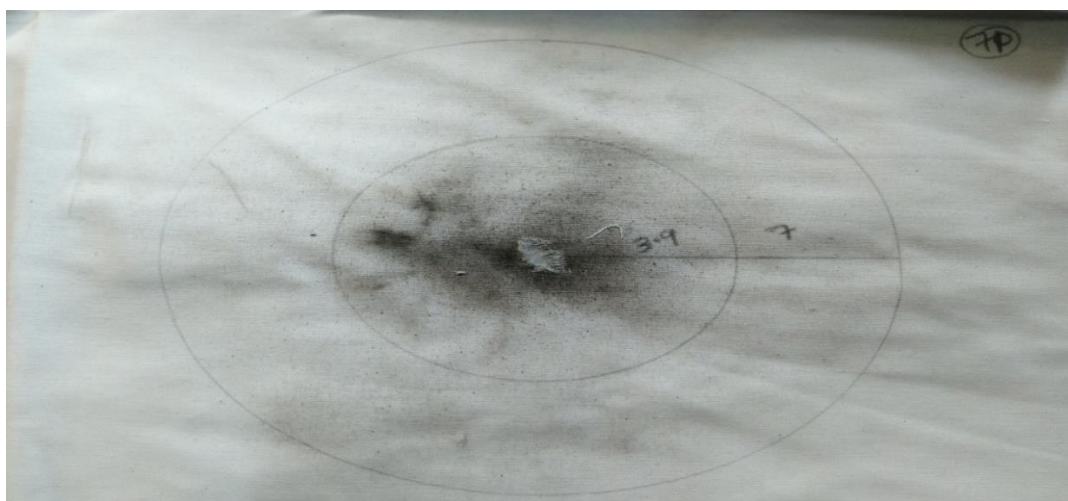


Fig 3. Showing Outer and inner dispersion area of GSR

In this fig.3., First we can draw outer circle near the outer dispersion pattern area, then we can draw 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.

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 π is 3.14, $A = 3.14 \times 7\text{cm} \times 7\text{cm} = 53.38 \text{ cm}^2(\text{app.})$

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 π is 3.14, $A = 3.14 \times 3.9\text{cm} \times 3.9\text{cm} = 47.75 \text{ cm}^2(\text{app.})$

In the same way dispersion pattern of GSR of both the calibre of countrymade pistol were calculated and a database is prepared. These tables can be used as database and we can calculate dispersion pattern of GSR from the sample recovered from the scene of crime and matches with this database of GSR Dispersion pattern. This can help in determining the approximate range of firing and type of calibre used in the crime.

Table. 1. Showing the GSR dispersion pattern of 7.65mm country made pistol on Cloth target from three different range

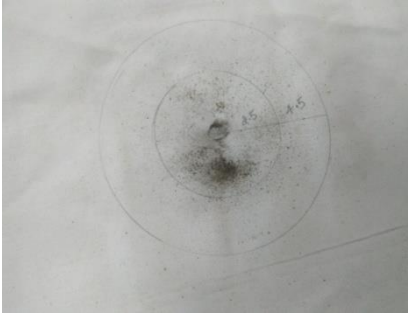
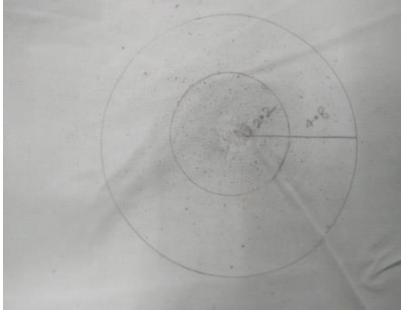
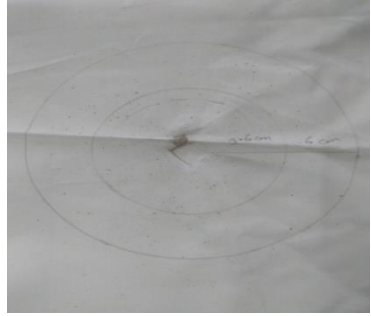
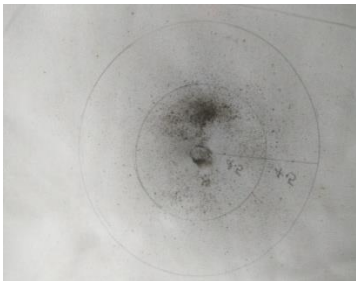
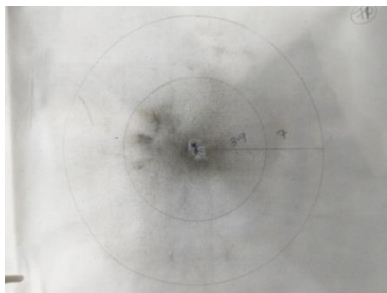
4" Range	8" Range	12" Range
		

Table. 2. Showing the dispersion pattern of .315"/8mm country made pistol on cloth target at three different range

4" Range	8" Range	12" Range
		

Now, Disersion pattern area of GSR is calculated, out of 30 samples, The table showing the average value of 10 samples of both the outer as well as inner dispersion area

Table 3. Showing outer and inner dispersion pattern area of GSR on cloth target fired by 7.65mm calibre of country made pistol at different ranges.

Dispersion Pattern Area	Samples									
	1	2	3	4	5	6	7	8	9	10
	Range 4"									
Outer 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
Inner 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"									
Outer 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
Inner 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"									
Outer 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
Inner 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

Table 4. Showing outer and inner dispersion pattern area of GSR on cloth target fired by .315"/8mm calibre of country made pistol at different ranges.

Dispersion Pattern Area	Samples									
	1	2	3	4	5	6	7	8	9	10
	Range 4"									
Outer Dispersion	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

Area										
Inner 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"									
Outer 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
Inner 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"									
Outer 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
Inner 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

Final values of Dispersion pattern area:

After analyzing all the samples their average can be take and database of three close range i.e. 4",8" and 12" can be prepared. This

database can be used for easy disposal of cases where range of firing is to ascertain . The tables mentioned below showing the values of dispersion pattern from each range

Table 5. showing comparison of dispersion pattern area on Cloth substrate fired by 7.65mm and .315"/8mm calibre of country made pistol 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.) O.D : 30-70 Cm ² (app.)	I.D : 80-95 Cm ² (app.) O.D : 280-300 Cm ² (app.)
8"	I.D : 20-30 Cm ² (app.) O.D : 70-120 Cm ² (app.)	I.D : 100-120 Cm ² (app.) O.D : 340-380 Cm ² (app.)
12"	I.D : 35-45 Cm ² (app.) O.D : 130-170 Cm ² (app.)	I.D : 130-150 Cm ² (app.) O.D : 410-470 Cm ² (app.)

The values of dispersion pattern of GSR has more potential in forensic firearm cases. Let us understand from an example. Suppose at scene of crime, Nothing was recovered from the crime scene except the body of the victim, no bullet

recovery, no cartridge case recovery and no firearm recovery. In this type of cases, we can calculate the area where dispersion of GSR particles takes place, as same as the method which is described in this study and the final

calculated value can be matched with the database prepared in this study. Then we give an estimate opinion from which range and from which calibre of firearms, firing took place.

2. Scanning electron microscopy analysis of GSR particles:

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 was 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 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. 4 Preparation of sample for SEM analysis

In SEM Examination of GSR Particles from 7.65mm & .315"/8mm calibre of country made firearm on cloth target, using KF (Khadki factory, pune) ammunition, it is found that, In case of 7.65 mm calibre on cotton cloth target, more number of particles of GSR observed at 4" distance, as the range increases, the no. of particles decreases because of their light weight, they can spread in air in all direction and the particle size of GSR increases as the range of firing increases because of more space they clump with each and become bigger in size. The particles of GSR at 4" distance is somewhat

spherical in shape. At the distance of 8", the particles of GSR is roughly spherical in shape. At the distance of 12", the particles size of GSR is of irregular spherical shape.

In case of .315"/8mm calibre of countrymade pistol on cotton cloth target, more number of particles of GSR observed at 12" distance, and nothing was found at 4" distance because of large size of ammunition. Very few particles are observed at 8" distance. The clumping of particles is more in .315"/8mm firearm and large GSR particles as compared to 7.65mm.

Table.6. Showing the morphology of GSR on cotton cloth target fired by 7.65mm calibre of country made pistol from three different close range

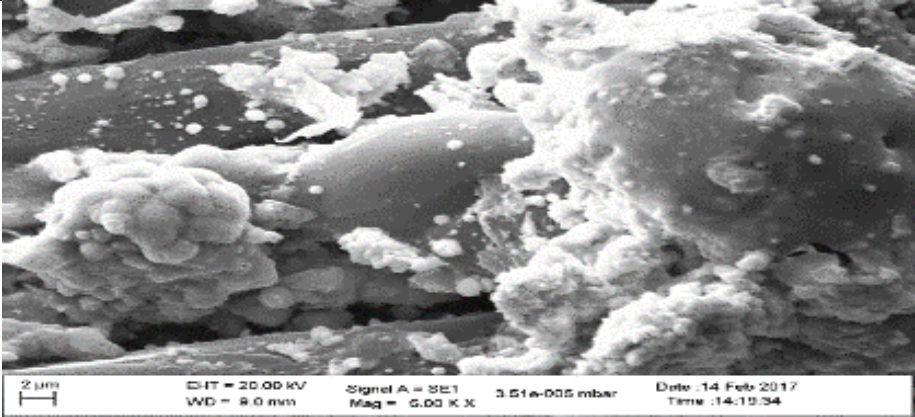
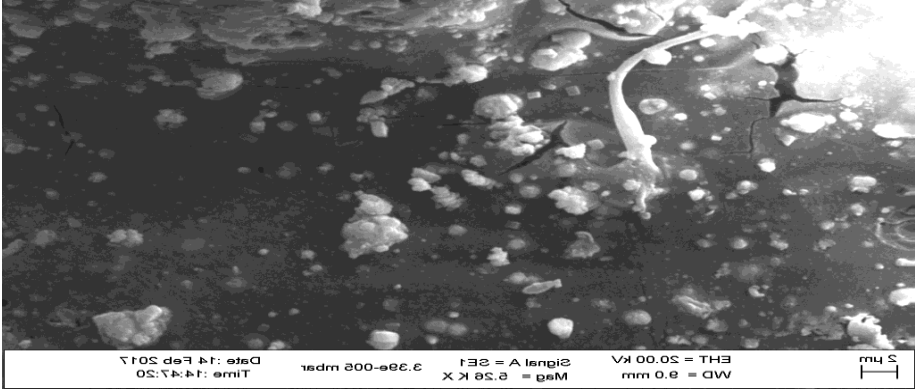
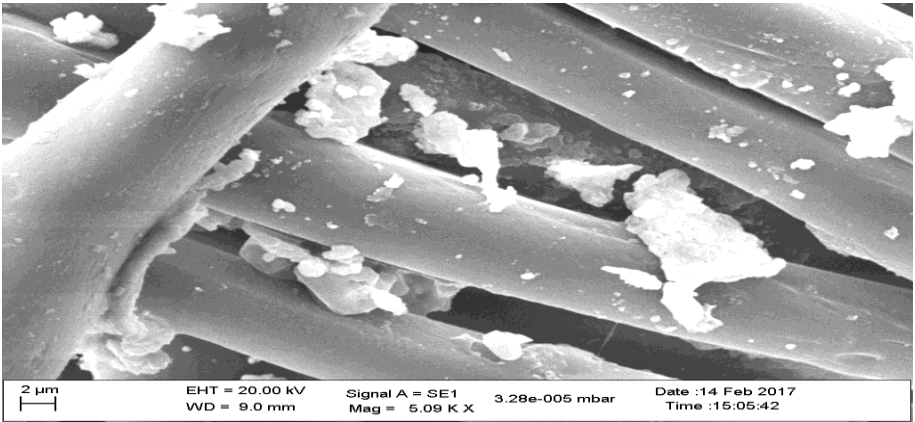
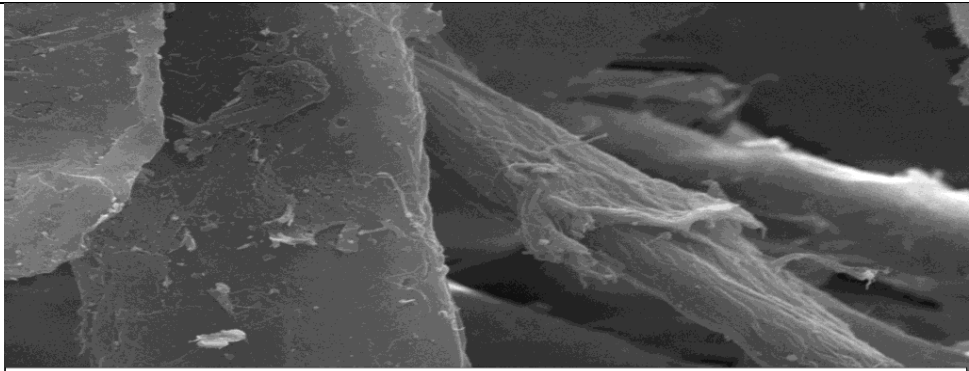
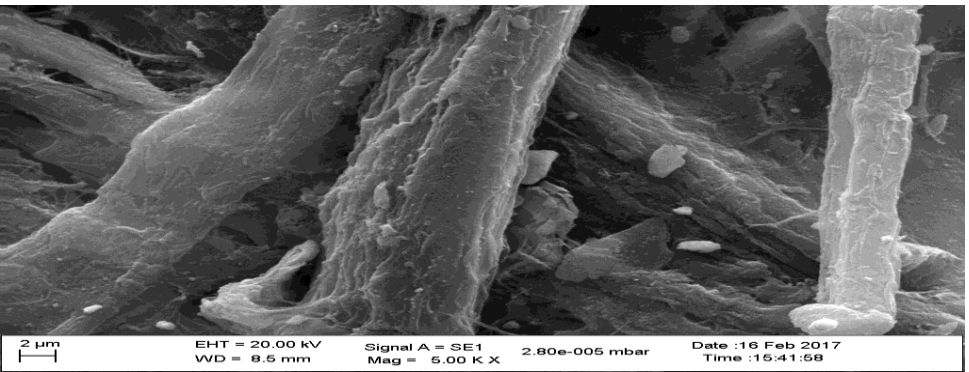
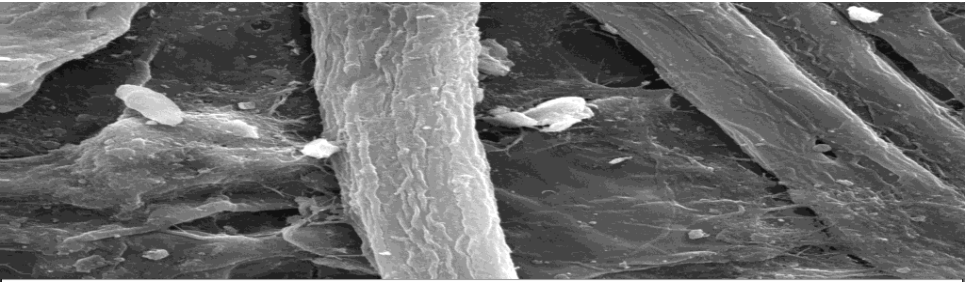
Range	7.65mm calibre of Country made Pistol on Cotton Cloth
4"	
8"	
12"	

Table.7. Showing the morphology of GSR on cotton cloth target fired by .315"/8mm calibre of country made pistol from three different close range

Range	.315"/8mm calibre of country made Pistol on Paper target
4"	 2 μm EHT = 20.00 kV Signal A = SE1 2.88e-005 mbar Date :16 Feb 2017 WD = 9.0 mm Mag = 5.00 K X Time :15:12:07
8"	 2 μm EHT = 20.00 kV Signal A = SE1 2.80e-005 mbar Date :16 Feb 2017 WD = 8.5 mm Mag = 5.00 K X Time :15:41:58
12"	 2 μm EHT = 20.00 kV Signal A = SE1 2.88e-005 mbar Date :16 Feb 2017 WD = 9.0 mm Mag = 5.13 K X Time :15:27:46

So, By analysing the morphology of GSR particles, we can also suggest that whether the firing was done from .315"/8mm calibre or 7.65mm calibre of countrymade pistol, Also we can find out the range of firing. This study can also help in where it is difficult to differentiate where the firing was done from standard or countrymade. It can easily differentiate between standard or countrymade firearm by the morphology of GSR.

3. Energy Dispersive X-rays Analysis of GSR particles

Energy Dispersive X-rays was carried out to determine the elemental composition of Gun Shot Residue. This is the final step to find out the type of firearm and range involved in crime. EDX detector works, to detect the elements present in the given sample. The samples which are taken from each range of different firearm run under EDX and much difference was

observed at different range and different calibre. Different combinations of elements are present at different range and from different weapon. This elemental detection database will help in determining range and type of firearm. Few combinations of elements are present at 4" range and absent in 12" range. Likewise, different combinations of elements are present in different calibre.

EDX analysis at different shooting distances

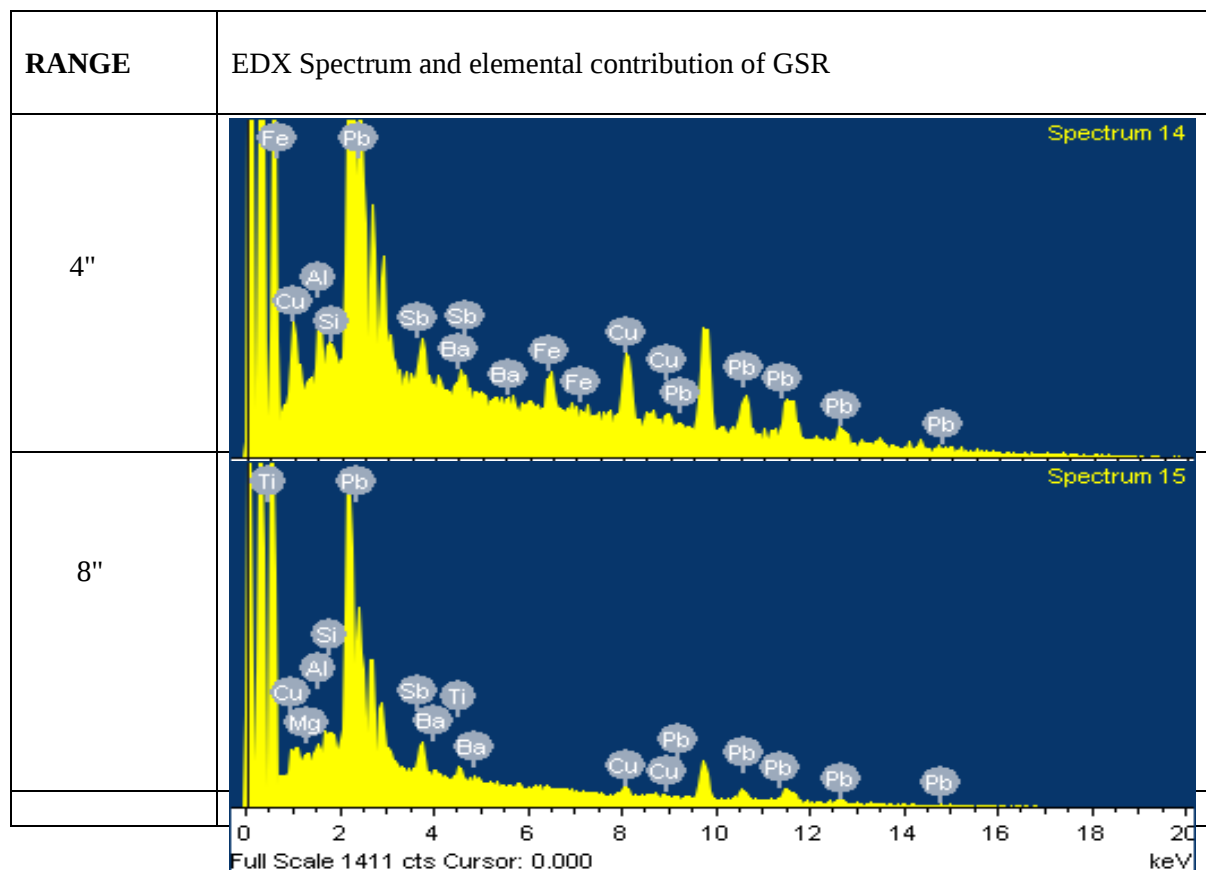
1. 7.65mm Calibre of Country made Pistol on Cotton Cloth Substrate

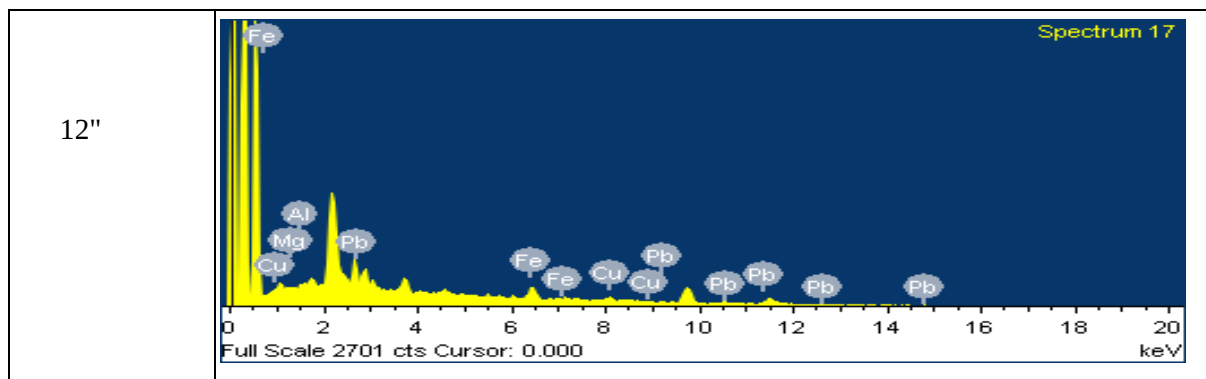
It is found that most important GSR Particles Pb, Ba, Sb were found up to 8" range of firing. But at 12" range of firing, Ba and Sb was absent, Pb was present.

Table.8. showing the important GSR elements present at three different close range Which are analysed under EDX

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

Table 9. Showing EDX spectrum and elemental contribution of GSR fired from 7.65mm calibre of Country made Pistol on Cotton Cloth Substrate





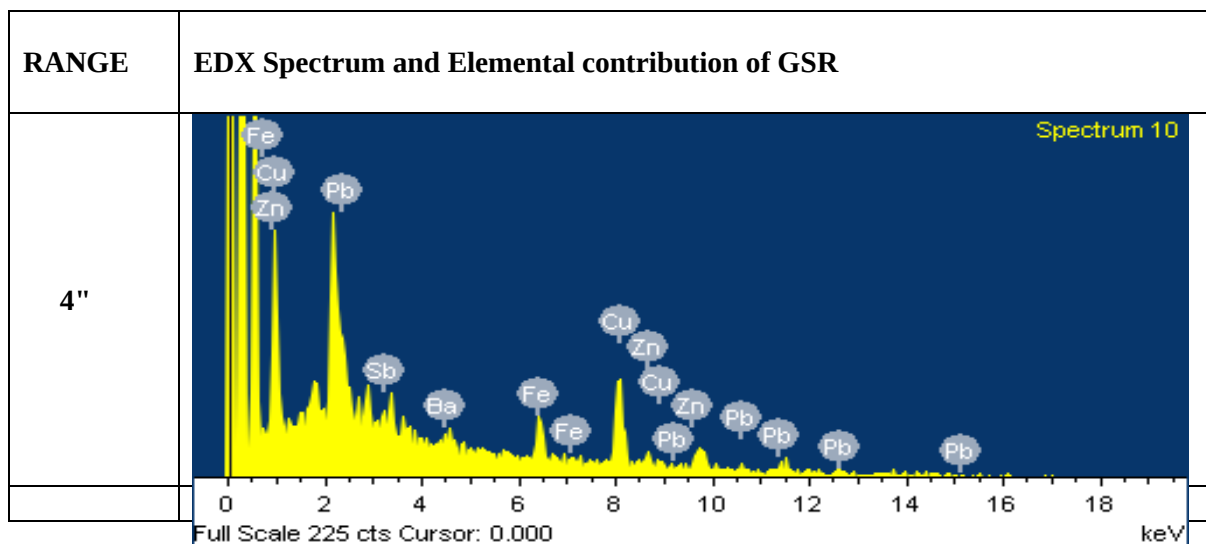
2. .315"/8mm calibre of Country made Pistol on Cotton Cloth Substrate.

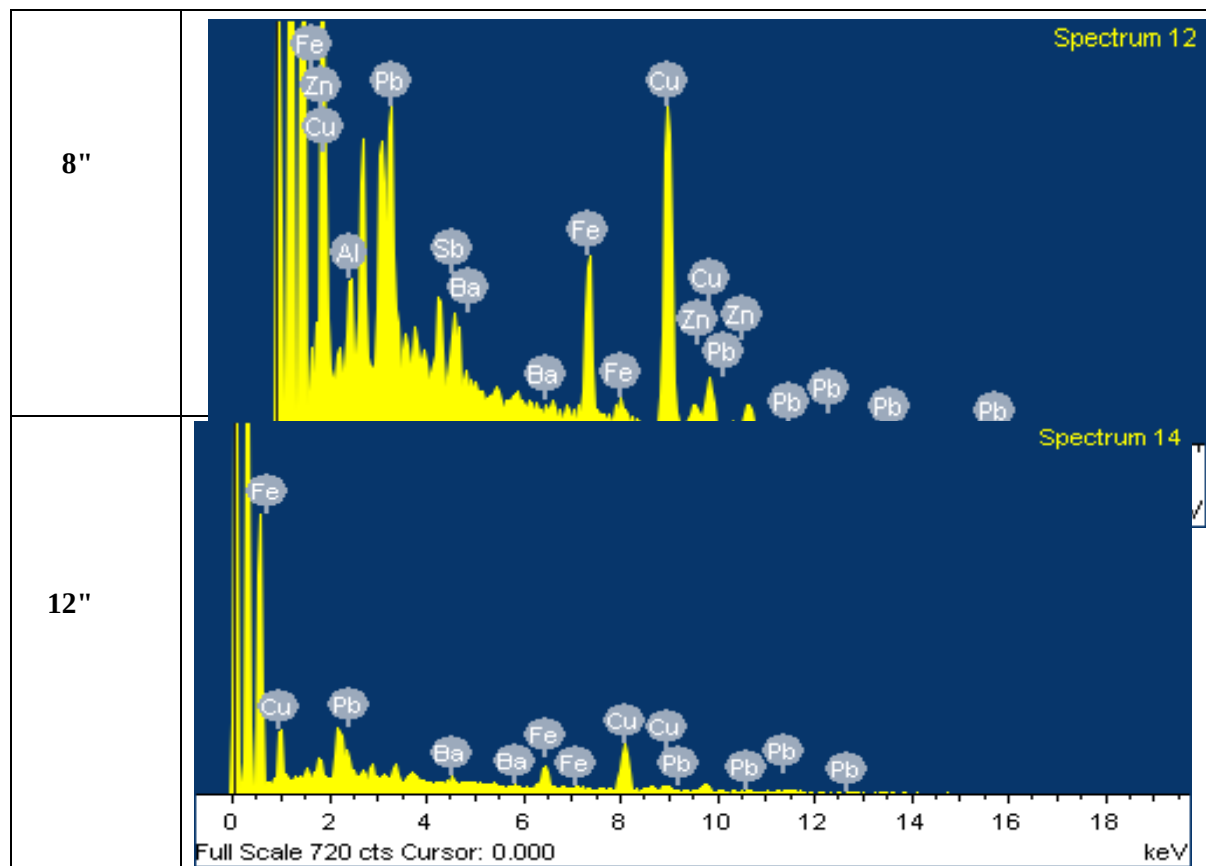
It is found that most important GSR Particles Pb,Ba,Sb were found up to 12" range of firing.

Table 10. 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

Table 11. Showing EDX spectrum and elemental contribution of GSR fired from .315"/8mm calibre of Country made Pistol on Cotton Cloth Substrate.





CONCLUSION:

In this study we demonstrate the methods for determination of muzzle-to-target distance based on GSR distribution and GSR pattern. The test firing was carried out at 4", 8" and 12" distances. The dispersion pattern area was calculated by using the formula of area of circle. The GSR was analyzed by SEM/EDX. Information gained from this study can be used to estimate muzzle to target distance for reconstruction of shooting distance up to 12 inch. It can also help to identify the calibre of firearm. SEM micrograph study revealed the geometrical shapes of GSR particles and EDX study revealed the composition percentage of elements generated from these two calibres of country made and Standard Firearms i.e. 7.65mm & .315"/8mm and ammunition on different Substrate. This study will help the forensic experts to dispose off the cases, where range of firing is to ascertain when countrymade firearm were used in the crime.

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