

Analysis of Gunshot Residue Deposited on Cotton Cloth Target at Close Range Shooting Distances

Mohamed Izzharif A. Halim^a, Umi Kalthom Ahmad^a, Chong-Hooi Yew^b, Muhammad Koey Abdullah^b

^a*Department of Chemistry, Faculty of Science, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia*

^b*Royal Malaysia Police Forensic Laboratory, Mile 8 ½, Cheras, Selangor, Malaysia*

ABSTRACT: The study of gunshot residue (GSR) has become imperative in forensic firearm examination. It may be used to estimate firing distance, to identify bullet holes and to determine whether or not a person has discharged a firearm. This study emphasized on the examination of the pattern of GSR particles deposited on cotton cloth target at different shooting distances (3 inch-12 inch). Two types of pistol (semiautomatic and revolver) and ammunitions (Syarikat Malaysia Explosive (SME) and Winchester) were used for the shooting test. All shooting tests were performed at Lapang Sasar of Pasukan Gerakan Am PDRM, Cheras. The results showed that GSR particles produced on cotton cloth by semiautomatic pistol using SME 9 mm ammunition generated higher amount and larger GSR particles which were almost completely burnt particles. The nitrite residues were confirmed using modified Griess test that revealed semiautomatic pistol produced considerable amount of nitrite residues. Scanning Electron Microscope (SEM) micrograph of GSR particles discharged from semiautomatic pistol using SME 9 mm ammunition revealed a mean particle size of 2.6 μm with spherical shapes. On the other hand, using revolver pistol with SME 0.38 Special ammunition, the GSR particles produced were small in amount. The modified Griess test also revealed that revolver pistol generated tiny amount of nitrite residues. Nevertheless, using Winchester 0.38 Special ammunition, the GSR particles discharge were of high amount and large in size which composed of completely unburned, partially burnt and completely burnt particles. Whereas SEM micrograph of GSR particles discharged from revolver pistol using Winchester 0.38 Special ammunition generated irregular cluster grain with a mean diameter of 3.3 μm . Sodium rhodizonate test was successfully applied for detecting the presence of lead residues around the bullet hole for both pistols.

Keywords: gunshot residue, modified Griess test, scanning electron microscope, sodium rhodizonate test.

Introduction

During investigative proceedings of incidents involving the use of firearms, forensic expertise can provide key elements for the court to reach an opinion. In such context, particular attention is usually drawn to evaluative issues associated with firearms and related evidence such as gunshot residues (GSR). Upon arrival at the scene, it is the responsibility of the police to start the difficult job of determining the sequence of events of the case especially when shooting is involved. When a gun is being fired, both burned and unburned powders from the propulsive charge as well as components from the primer, the bullet and the cartridge case form a cloud that may cause a roughly circular pattern around the bullet hole upon contact which is called GSR [1].

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 [2]. However, there is increasing pressure from the

judicial system to identify an ammunition type, and hence the weapon type which may have been involved in an incident based on GSR collected [3]. Thus, this study emphasize on the pattern of GSR on cloth target for different pistols and ammunition used.

It is apparent that collecting cloth evidence bearing GSR has more potential for providing inculpatory evidence in some cases than bare hand sampling. GSR retained on clothing are considerably longer than skin surfaces resulting in a high probability of their detection and identification from that source [4]. If someone is standing close enough to the gun as it is fired, the GSR will appear on the person's clothing. Thus, the estimation of distance from the weapon's muzzle to target material of clothing may be in an important factor in an investigation [5].

The pattern of gunshot residue may vary with different distances [6]. Numerous studies have been published on the analysis of GSR by various analytical methods. At close distances when many smokeless powder particles are present on target

material, a typical pattern can be established by the modified Griess test and hence the shooting distance can easily be estimated [7]. Another chemical test used to estimate the firing distance is known as sodium rhodizonate test which is used as a spot test for lead residues [8]. Therefore, these chemical tests were used in this study to restore insufficient interpretation of GSR pattern from visual examination by the naked eyes as well as microscopy.

Experimental

Chemicals and Materials

The chemical reagents needed for the chemical tests were sodium rhodizonate, sodium bitartrate from Sigma Aldrich, Germany; tartaric acid, sodium nitrite and methanol from QReC; hydrochloric acid from J. T. Baker, Mexico; and sulfanilic acid, alpha-naphthol and glacial acetic acid from Merck from Germany. The chemicals were all of analytical grade from a range of suppliers. Two types of pistol used for the shooting test were a 0.38 Revolver Smith & Wesson (serial number: D943607 from USA) and a 9 mm semi-automatic Yavuz 16 Compact (serial number: T 0624-06 TF 022891 from Russia). The ammunition used were Syarikat Malaysia Explosive (SME) 9 mm with full metal jacketed (FMJ) round nose design, SME 0.38 Special with lead round nose (LRN) design and Winchester 0.38 Special with lead round nose (LRN) design. In order to perform chemical tests, uncontaminated iron (Panasonic brand), plastic tray, spray bottle (300 mL), filter paper (A4 size) and cotton swab were procured. Other materials and apparatus (stand, soft plastic cardboard pad, stick to hold the cloth item) relating to the shooting tests were provided by PDRM. A Nikon D60 18-55 VR Kit digital camera (made in Japan) was used to photograph the GSR images.

Instrumentation

Scanning electron microscope (SEM) model FEI Quanta 200F equipped with xT Microscope Control software was employed for morphological and microstructure of GSR particles.

Target Material and Firearm Preparation

Cotton cloth targets (25 cm x 25 cm) were used for the shooting test. Each cloth was placed over a 60 x 65 cm soft plastic cardboard pad and stapled to it. The soft plastic cardboard padding which was fixed to a wooden frame stand was 115 cm above the ground. The cloth was not stretched but pulled tight enough to eliminate wrinkles in the fabric. The stand bearing the cloth target was then positioned

at different distances from the shooter. Two types of firearm, a 0.38 Revolver Smith & Wesson and a 9 mm semi-automatic Yavuz 16 Compact were prepared. Prior to firing on the cloth target, at least three shots were fired to safe target area in order to ensure that the barrels will be coated with smoke and powder residues for the whole series of shots to the target samples. The set-up for this experiment and all shooting were performed by specialized police officers at Lapang Sasar Pasukan Gerakan Am (PGA) PDRM, Cheras.

Shooting Test

The objective in this shooting test was to estimate the effective firing distance from the muzzle to the cloth target. The distances were focused at close ranges which were 3, 6, 9 and 12 inches. These distances were chosen in this shooting test as the nitrite is only effectively detected at the distance less than 15 inch (Jeffrey, 1998). The shots were tested at 90 degrees to the target. Each of the distance was repeated three times so that the modified griess test (MGT) and sodium rhodizonate test (SRT) could be applied on separate cloth target bearing the GSR.

Chemical Tests

For the modified Griess test, the pre-cut sheets of filter paper (A4 size) were briefly submerged in the mixture consisted of a solution of 0.5 g of sulfanilic acid in 100 mL of deionized water and a solution of 0.28 g of alpha-naphthol in 100 mL of methanol. Then, 15 % acetic acid was sprayed on the cloth bearing GSR particles on the side of bullet entrance. Then, the sample was placed face down on the filter paper. Again, acetic acid was sprayed but on the side of bullet exit until the cloth was dampened. The layers were pressed with a hot uncontaminated iron. Acetic acid steam was forced through the layers, causing the colour-producing reaction. The cloth item was then separated from the filter paper. An orange colouration on the paper indicates the presence of nitrite residues.

For sodium rhodizonate test, the test area was initially sprayed with the saturated solution of sodium rhodizonate. The solution was prepared by dissolving a small amount of sodium rhodizonate (about 0.2 g) in 100 ml deionized water to form a saturated solution that was approximately the colour of dark tea. After that, the same area was then sprayed with the buffer solution. The buffer solution was prepared by dissolving 1.9 g of sodium bitartrate and 1.5 g of tartaric acid in 100 mL of deionized water. The resulting solution was heated on a hot plate while agitating with a magnetic stirrer to produce a pH 2.8 buffer solution. This solution eliminates the yellow background

colour caused by the sodium rhodizonate, establishes a pH 2.8, and displays a pink colour in the presence of lead.

SEM analysis

Scanning electron microscopy (SEM) of individual particle analysis was employed for this study to examine the characteristic GSR particles. As the GSR is non-conductive, low vacuum mode was used. GSR were sampled from the cloth target by carefully pressing the double-sided carbon base tape cut to 8 mm in length onto cloth bearing GSR particles. Subsequently these tapes were fixed to a cylinder that was rotated within the SEM chamber and adjustable in an axial direction. The tapes bearing GSR particles were scanned for possible GSR particles with simultaneous SE and X-ray imaging. The outcome was a microstructure image of the GSR particles with desired magnification.

Results and Discussion

(A) Semiautomatic Pistol

GSR at different shooting distances

1) Visual Examination

The estimation of shooting distance were first made based on the direct and visual examination of the cloth target and then treatment with specific chemical reagents as stated by proposed by previous researchers [9]. Sodium rhodizonate test, a method that would reveal the GSR pattern on the item *in situ* can minimize the loss of the GSR during the transfer of the evidence. Whereas, modified Griess test needs to be performed in the laboratory as it requires troublesome procedures. The shooting distances selected were 3, 6, 9, and 12 inches. After the cloth target was shot, the pattern of the GSR produced was photographed using a Nikon digital camera before subjected to further chemical tests. There were three areas in the GSR pattern that need to be observed and examined which were the plume line, particle and sooting of GSR. These three areas could serve as the indicator for the characteristic of the pattern of GSR at different shooting distance. **Fig. 1** shows the appearances of cotton cloth shot using semiautomatic and revolver pistols respectively at different shooting distances.

2) Modified Griess Test

When a firearm is discharged, nitrite particles are expelled from the muzzle of a firearm and can be imbedded in or deposited on the surface of a target. Nitrite residues are by-products of completely burnt particles of smokeless gunpowder.

Therefore, the modified Griess test is a test to detect the presence of nitrites residues. After visually examine an exhibit of a real case, modified Griess test could be applied to determine a muzzle-to-garment distance. The colour of orange specks on the filter paper were the result of chemical reaction involved between acetic acid vapors (steam ironing on the back of cloth target), nitrite residues and the chemicals contained in the filter paper [9]. For cloth target shot using semiautomatic at different shooting distances, intensity of the orange colouration decreased with increasing distance of muzzle-to-target. This implied that nitrite residues could still be detected up to 12 inch shot distance. It is estimated beyond 15 inch muzzle-to-target distance, nitrite residue could not be detected on the cloth bearing GSR fired by both types of pistols. This is in agreement with that reported by previous study [10].

Another test conducted on the cloth bearing GSR was the sodium rhodizonate test. Information from this test may also assist in establishing a muzzle-to-target distance. The positive test for sodium rhodizonate test indicates that the lead may originate from lead-bearing bullet or/and vaporous lead residue from the primer. The test was performed by spraying the exhibit with a weak solution of sodium rhodizonate followed by a buffer solution which caused the background colour to disappear. The reagent reacted with any lead that may be present and produced very bright pink colour. At a firing distance of 3 inch, an intense pink circular colouration around the bullet hole was clearly visible on cloth target fired using semiautomatic pistol. With increasing firing distance from 3 to 12 inch, the pink circular colouration appeared to be less intense. For distance of 12 inches, the pink colouration was very tiny indicating that the lead residue could only be detected up to 12 inch away from the cloth target. The diameter of the pink colouration gradually decreased and the pink colouration became less intense with increasing distance. Therefore, it indicated that the lead residues were only present in considerable amount at very close firing distance.

3) Sodium Rhodizonate Test

It is found that the particles appeared as spherical shape with an average diameter 1.5 μm . Some of them were perfect spheres, sometimes hollow, and minor were irregular and distorted which is in close agreement with previous study [11].

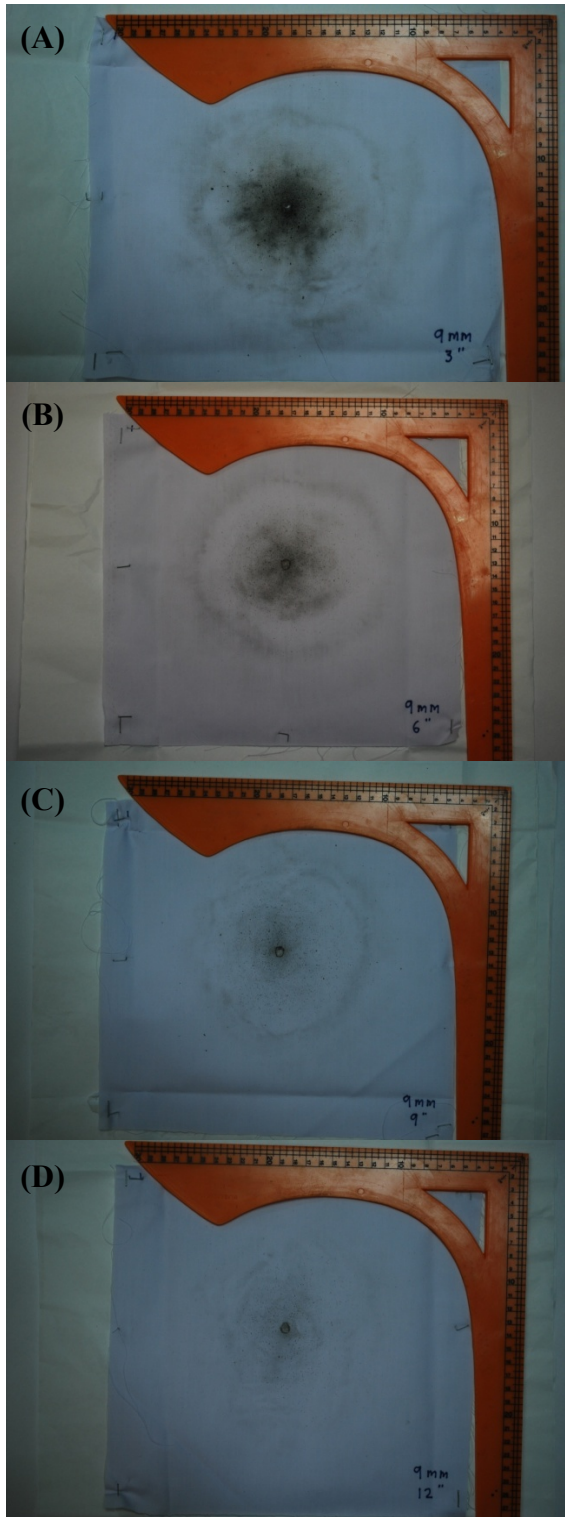


Fig. 1: Pattern of GSR on cotton cloth fired using semiautomatic pistol at different firing distances (A) 3 inch, (B) 6 inch, (C) 9 inch and (D) 12 inch.

Scanning Electron Microscopy

Scanning electron microscope was carried out to determine the morphology and microstructure of the GSR particles. For the examination, GSR were

collected from the cloth using double-backed carbon tape SEM stub. It was then placed on the SEM stage for further examination. By means of computer system, the stub was scanned to locate specific area that could produce an image of the GSR particles either by low or high magnification. **Fig. 2** represents SEM micrograph for a GSR particle discharged from semiautomatic pistol using SME 9 mm ammunition.

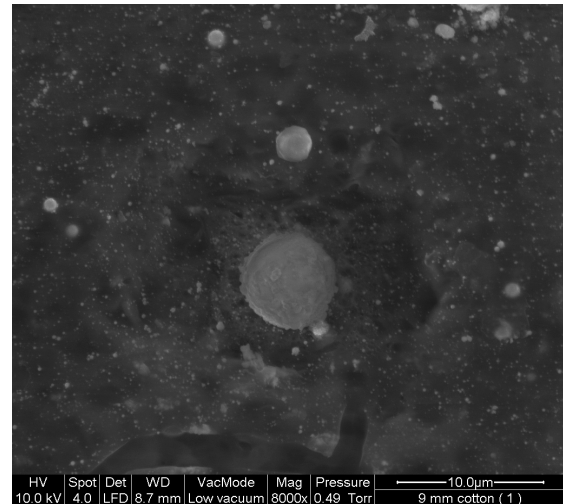


Fig. 2: SEM micrograph for GSR particles discharged from semiautomatic pistol using SME 9 mm ammunition at 8000x magnification.

(B) Revolver Pistol

GSR at different shooting distances

1) Visual Examination

In this study, the pattern of GSR deposited on cloth target for revolver pistol was also investigated. All the methods and procedures involved when dealing with semiautomatic pistol were repeated for the revolver pistol. Therefore the examination and analysis for the GSR produced using revolver pistol were based on semiautomatic pistol in order to estimate the shooting distance. **Fig. 3** shows the GSR pattern generated on cotton cloth target using revolver pistol.

2) Modified Griess Test

After visual examination, the cloth target bearing GSR were subjected to the modified Griess test to visualize the nitrite residues expelled from the revolver pistol. As in modified Griess test for semiautomatic pistol, the colour of orange specks on the filter paper appeared as a result of chemical reaction involved. As expected, the intensity of the orange colouration decreased with increasing distance of muzzle-to-target. However, the orange specks appeared on the filter paper were not too

intense and crowded. It shows that the revolver pistol generated little amount of nitrite residues. Yet, it is believed that the nitrite residues could still be detected up to 15 inch because there was still nitrite residues observed on the filter paper at distance of 12 inch.

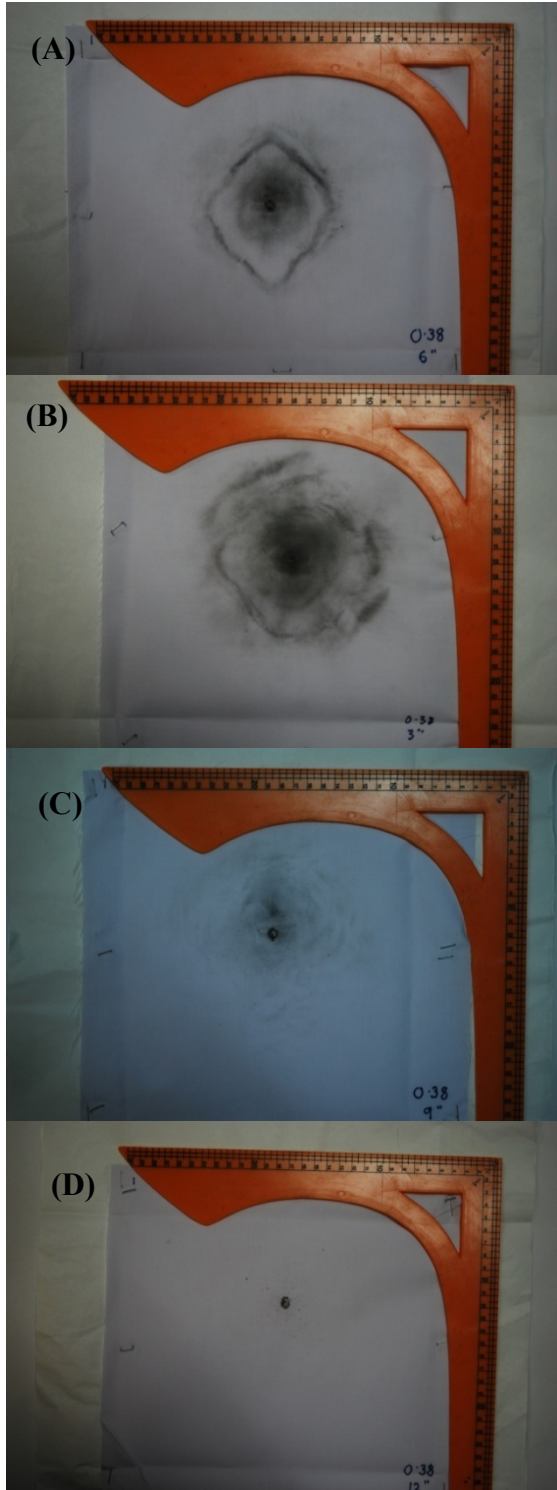


Fig. 3: Pattern of GSR on cotton cloth fired using revolver pistol at different firing distances (A) 3 inch, (B) 6 inch, (C) 9 inch and (D) 12 inch

3) Sodium Rhodizonate Test

The subsequent chemical test treated was sodium rhodizonate test. The cotton cloth target bearing GSR expelled from revolver pistol was sprayed with sodium rhodizonate solution and buffer solution to observe the appearance of pink colour as a result of chemical reaction. The diameter of the pink colouration gradually decreased and the pink colouration became less intense with increasing distance. However, the pink pattern was difficult to visualize beyond 9 inch. Results of this study indicated that lead residues from vaporous lead smoke (primer) could only be detected up to 9 inch for the revolver pistol. But, at the bullet ring, the pink colouration could be observed by thoroughly examination. This showed that the bullet contained lead bearing material.

Scanning Electron Microscopy

SEM micrograph is made by examination of GSR particle discharged from revolver pistol using ammunition of Winchester .38 Special (**Fig. 4**).

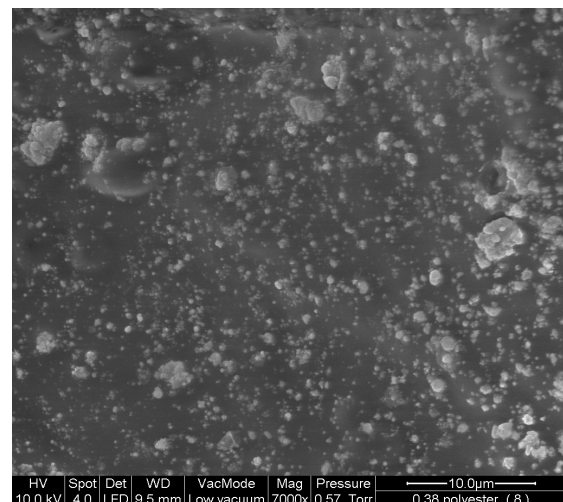


Fig. 4: SEM micrograph for GSR particles discharged from revolver pistol using Winchester 0.38 Special ammunition at 7000x magnification.

It found that the particles appeared as irregular cluster group grain of 3.3 µm in diameter. The difference in geometrical shape of GSR particle is possibly due to the different manufacturing process that produced the kind of ammunition. Another factor that could contribute to the different shape is the fact that different process was involved in formation of the particles for the semiautomatic and revolver pistols. The particles undergo different paths that gases and forming particulate take upon escape from the pistols. In revolver pistol, most of the gases from the primer burn escape in the area around the cylinder, whereas in the

semiautomatic pistol, the initial path is the opening provided by the ejection port [8].

Conclusion

Information gained from this study can be used to estimate the muzzle-to-target distance for reconstruction of shooting test up to 12 inch. Chemical analyses involving modified Griess test and sodium rhodizonate were successfully employed. Results of modified Griess test corroborated the visual examination as orange specks revealing the presence of nitrite residues. Whereas results indicated that both pistol discharge contained lead from the positive colour change on the cloth target. SEM micrograph from this study revealed the geometrical shapes of the GSR particles generated from different pistol and ammunition.

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Additional information and reprint requests:
 Mohamed Izzharif Bin Abdul Halim
 (Email: izzharif@salam.uitm.edu.my)
 Chemistry (Forensic Analysis) Program
 Faculty of Applied Sciences
 Universiti Teknologi MARA
 40450 Shah Alam, Selangor, Malaysia