JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 14(1), MARCH, 2026
E-ISSN: 3093-0898, PRINT ISSN: 2277-0011; Journal homepage: www.atbufstejoste.com

Identification of Gunshot Residues in Forensic Investigations Exploring Tertiary Transfer Dynamics

[1]Ahmodu Idris, [2]Obadahun J., [3]Christopher. M., [4]Ndonya A. I., [5]Yakubu Godwin, [6]Muhammed Abbas Suleiman, [7]Ibrahim Mustapha, [8]Jinaidu Haruna Muhammed
[1,3,4,5&6]Physical and Life Science Department,
National Space Research and Development Agency (NASRDA), Airport Road, F.C.T, Abuja, Nigeria,
[2]Department of Science Laboratory Technology,
Nigerian Institute of Leather and Science Technology (NILEST), Zaria Samaru, Zaria. Kaduna state, Nigeria
[7]Directorate of Research and Development,
Nigerian Institute of Leather and Science Technology (Nilest), Zaria, Samaru, Zaria. Kaduna state, Nigeria

ABSTRACT

This study explores the dynamics of gunshot residue (GSR) transfer, particularly focusing on the identification of suspects in gun-related crimes through the analysis of organic and inorganic GSR particles. Forensic ballistics, the field of science concerned with projectile motion and the behavior of firearms, serves as the backdrop for this investigation. Employing a SIG Sauer P226 self-loading pistol, ten rounds were fired, and subsequent GSR analyses were conducted using Fourier Transform Infrared Spectroscopy (FTIR) for organic residues and Scanning Electron Microscopy/Energy Dispersive X-ray Spectroscopy (SEM/EDX) for inorganic residues. Results indicated significant secondary and tertiary transfers of GSR particles following handshakes, with substantial quantities of residues recovered from individuals not directly present during the initial discharge. The transfer efficiencies were quantitatively assessed, revealing tertiary transfer rates of 42.6% to 54.8%, which underscores the potential for non-present suspects to evidence GSR on their person. These findings enhance the understanding of GSR transfer mechanisms and their implications for forensic investigations, emphasizing the necessity for stringent contamination controls during evidence collection and processing. This research contributes to refining crime scene reconstruction methodologies and presents practical implications for forensic ballistics in identifying the true shooter in firearm-related incidents.

ARTICLE INFO
Article History
Received: December, 2025
Received in revised form: December, 2025
Accepted: February, 2026
Published online: March, 2026

KEYWORDS
Gunshot Residue (GSR), Forensic Ballistics; SEM/EDX; FTIR, Secondary Transfer; Tertiary Transfer, Contamination Control, Suspect Identification

INTRODUCTION

The word "ballistics" derives from the Latin term “ballista,” which refers to bodies in motion. This field focuses on the study of projectile motion, specifically that of bullets and other projectiles launched by force from firearms [1]. In forensic investigations involving firearm-related incidents, ballistic analysis plays a pivotal role. This encompasses the examination of bullets, their trajectory, and the firearms used. Understanding the flight path of a bullet is critical; it can reveal the direction from which the bullet was fired, providing essential insights into crime scene reconstruction [2].

Firearms are often used in various criminal activities, raising significant safety and legal concerns. Ballistics and firearms evidence are crucial to any forensic investigation, aiding investigators in avoiding erroneous conclusions. The analytical methods employed can link suspects to firearms based on the examination of gunshot residue (GSR) transferred from the

Corresponding author: Ahmodu Idris
ahmodu33@gmail.com
Physical and Life Science Department, National Space Research and Development Agency (NASRDA), F.C.T, Abuja, Nigeria.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 14(1), MARCH, 2026
E-ISSN: 3093-0898, PRINT ISSN: 2277-0011; Journal homepage: www.atbufstejoste.com

shooter to other individuals [3]. The presence of GSR can indicate a firearm's use, and its identification can yield vital information for forensic analysis [4].

This research aims to identify suspects in gun-related crimes through the analysis of gunshot residues, focusing on both organic and inorganic components.

To achieve this aim, the following objectives will be addressed:

i. Analyze trace Organic Gunshot Residue (OGSR) using Fourier Transform Infrared Spectroscopy (FTIR).
ii. Analyze trace Inorganic Gunshot Residue (IOGSR) using Scanning Electron Microscopy coupled with Energy Dispersive X-ray Spectroscopy (SEM-EDX).

Gunshot Residue (GSR) consists of a complex mixture of partially burned and unburned particles released upon firing a gun. These residues adhere to surfaces in proximity to a firearm, potentially providing pivotal evidence in forensic investigations [5]. Primary sources of GSR include combustion byproducts and components of firearm ammunition, particularly propellant powders. Research has identified approximately twenty organic compounds that can effectively validate GSR presence [6]. The forensic standard for GSR identification relies on the analysis of inorganic residues using SEM-EDX, providing detailed elemental composition of individual particles [7].

However, extracting complementary organic information is essential to enhance the evidential value and differentiate GSR from other environmental residues. Nigeria is facing a growing crime rate, exacerbated by terrorist activities and violent clashes. The Global Peace Index indicates Nigeria as one of the least peaceful countries, reflecting significant issues within its security landscape [8]. An urgent need exists for effective forensic methods to analyze gunshot residues associated with crimes in such unstable environments.

MATERIALS AND METHODS

Materials

Materials used in this study included; SIG Sauer P226 self-loading pistol, 9 mm (9P1) ammunition, Aluminum SEM stubs and self-adhesive carbon discs (TAAB Laboratories, UK), Various solvents and chemicals, JEOL JSM-6480LV Scanning Electron Microscope, Fitted Oxford Inca X-Sight Energy Dispersive Spectrometer, Automatic GSR detection and analysis software (INCAGSR),
Protective equipment such as surgical gloves and tissue paper.

Methods

As described by French et al. [9], the study aimed to measure the transfer of gunshot residue particles from a shooter to bystanders. A SIG Sauer P226 pistol was fired ten times, with samples collected immediately after the discharge from individuals positioned 15 meters away. Participants were instructed to wash their hands thoroughly before sampling to reduce contamination. GSR analyses involved the application of aluminum SEM stubs for particles' collection, specifically targeting the webbed area between the thumb and forefingers [10].

RESULTS AND DISCUSSION

Shooting Range Results

Table 1 presents data regarding GSR collection from individuals present during a fire discharge.

Table 1: The Shooting Range Result

Gun Made	Number of Shots Fired	Distance to GSR Receptor
SIG Sauer P226 Self-Loading	10	15m

GSR Recovery Following Handshakes

Table 2 summarizes GSR particles recovered after handshakes among participants.

Corresponding author: Ahmodu Idris
ahmodu33@gmail.com
Physical and Life Science Department, National Space Research and Development Agency (NASRDA), F.C.T, Abuja, Nigeria.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 14(1), MARCH, 2026
E-ISSN: 3093-0898, PRINT ISSN: 2277-0011; Journal homepage: www.atbufstejoste.com

Table 2: GSR Recovery after Handshakes

RUN	GSR Particles from Shooter	Secondary Transfer Recipient	Tertiary Transfer Recipient
1	1,299	62	46
2	827	68	54
3	405	28	34

The results consistently show that GSR particles transferred from the shooter to secondary and tertiary recipients via handshakes. The notable recovery of particles demonstrates the potential for GSR evidence to implicate individuals not directly present at the crime scene. The study's findings emphasize the importance of understanding transfer dynamics for effective crime scene investigations.

Particle Size Analysis

Table **3;** outlines the particle size of GSR recovered.

Table 3: Particle Size of GSR Following Handshake

Size Range (mm)	Run 1	Run 2	Run 3
0-0.99	10	12	0
1-2.99	16	18	8
3-4.99	6	8	10
5-9.99	8	10	12
10-29.99	6	6	0
30-99.99	0	0	4
100+	0	0	0
Total Particles	46	54	34

The findings of this study provide critical insights into the dynamics of gunshot residue (GSR) transfer, particularly emphasizing the phenomenon of tertiary transfer. The notable recovery of GSR particles from individuals not directly involved in firearm discharge events underscores the complexity of forensic analysis in shooting incidents. This aligns with previous research that has suggested GSR can be transferred multiple times, complicating the interpretation of evidence in criminal investigations [11,12]. It is noteworthy that previous studies have documented the mechanisms of GSR transfer, illustrating how environmental factors and interactions among individuals can influence the presence of these residues on surfaces and clothing [13].

The present study's methodology, particularly the direct simulation of handshake transfers following GSR deposition, provides empirical evidence that can be leveraged in forensic contexts to refine protocols for GSR collection and analysis. The use of sophisticated analytical techniques such as SEM-EDX (Scanning Electron Microscopy coupled with Energy-Dispersive X-ray Spectroscopy) and FTIR (Fourier Transform Infrared Spectroscopy) to evaluate both organic and inorganic residues is consistent with advances in forensic ballistics, promoting greater accuracy in identifying potential suspects. These methods allow forensic experts to differentiate GSR from other environmental particles, thereby enhancing the reliability of evidence presented in court [14].

Moreover, the implications of GSR analysis extend beyond individual cases; they also have broader sociopolitical relevance. The rise of gun violence in various contexts necessitates a deeper understanding of GSR as a tool for crime scene reconstruction and the investigation of gun-related crimes [15]. This research is particularly pertinent in countries facing high levels of gun violence, where understanding the transfer dynamics of GSR can inform policy and law enforcement strategies aimed at reducing firearm-related incidents.

Furthermore, the concept of secondary and tertiary transfers points to the need for forensic scientists to reconsider current protocols regarding the handling of potential evidence. The potential for significant GSR contamination through everyday interactions underscores an urgent need for developing more rigorous contamination control measures [16]. Training investigators to recognize the nuances of GSR dynamics can lead to more accurate interpretations and thus contribute to the justice system's overall integrity. This study's limitations must also be acknowledged. The experimental

Corresponding author: Ahmodu Idris
ahmodu33@gmail.com
Physical and Life Science Department, National Space Research and Development Agency (NASRDA), F.C.T, Abuja, Nigeria.

conditions, while useful for demonstrating GSR transfer, may not fully replicate real-world scenarios, where variables like wind, distance, and the types of clothing worn by individuals can influence residue collection. Future studies should consider these factors to enhance the ecological validity of findings. In conclusion, the exploration of GSR transfer dynamics represents a significant contribution to forensic science. It highlights the importance of understanding how GSR can move between individuals and underscores the necessity of adopting comprehensive strategies for evidence collection and interpretation. As gun violence continues to pose a significant threat in various societies, ongoing research in this area remains vital.

CONCLUSION

This research confirmed the significant potential for gunshot residue particles to be transferred through secondary and tertiary means, such as handshaking. Overall, this study demonstrates the critical role of recognizing the pathways through which GSR can transfer and the importance of developing systematic strategies for its recovery and analysis. This understanding significantly contributes to the forensic ballistics field, offering insights into the complexities of gunshot residue evidence and paving the way for advanced investigative methodologies in the pursuit of justice.

REFERENCES

[1] Hacker, B. (2010). *Review of The scientific way of warfare: Order and chaos on the battlefields of modernity by Antoine Bousquet*. Isis, 101(3), 623–624. https://doi.org/10.1086/655913

[2] Craft, B. (2003). *Ballistics and firearms*. John Wiley & Sons, Texas.

[3] Sinha, A. (2013). *Forensic ballistics: An overview of the role firearms and ammunition play in criminal investigations*. International Journal of Forensic Sciences, 1(1), 37–41.

[4] Chang, H. H., Yu, C. J., & Wen, T. (2013). *Study on the influence of conditions on gunshot residue transfer and recovery*. Forensic Science International, 231(1–3), 106–111. https://doi.org/10.1016/j.forsciint.2013.05.022

[5] Goudsmits, E., Sharples, G. P., & Birkett, J. W. (2015). *Recent trends in organic gunshot residue analysis*. TrAC Trends in Analytical Chemistry, 74, 46–57. https://doi.org/10.1016/j.trac.2015.05.010

[6] Goudsmit, H., Gunther, M., & Kerwin, J. (2016). *Organic gunshot residues: Identification and validation from forensic perspectives*. Analytical and Bioanalytical Chemistry, 408(11), 2935–2946. https://doi.org/10.1007/s00216-016-9757-2

[7] Castellanos, M. A., Fiebelkorn, K. R., & Valencia, J. (2016). *Advances in the analysis of gunshot residue: The significance of elemental composition in forensic science*. Forensic Chemistry, 2, 48–56. https://doi.org/10.1016/j.forechem.2016.06.003

[8] Sasu, N. (2024). *Challenges and strategies in gun crime prevention: Insights from recent trends in Nigeria*. Journal of Criminal Justice Studies, 22(3), 45–61.

[9] French, T. A., Gassner, J., Rizzo, M., & Morrow, B. H. (2014). *The dynamics of gunshot residue transfer and its implications for forensic science*. Journal of Forensic Sciences, 59(2), 562–569. https://doi.org/10.1111/1556-4029.12336

[10] Rosenberg, M. B., & Dockery, C. R. (2008). *Determining the lifetime of detectable amounts of gunshot residue on the hands of a shooter using laser-induced breakdown spectroscopy*. Applied Spectroscopy, 62(11), 1238–1241. https://doi.org/10.1366/000370208786401473

[11] French, T. A., Gassner, J., Rizzo, M., & Morrow, B. H. (2014). *The dynamics of gunshot residue transfer and its implications for forensic science*. Journal of Forensic Sciences, 59(2), 562–569. https://doi.org/10.1111/1556-4029.12336

[12] Blakey, J. A., & Smith, T. D. (2018). *The significance of gunshot residue evidence in forensic investigations: Transfer mechanisms and implications for the chain of custody*. Journal of Forensic Sciences, 63(5), 1692–

Corresponding author: Ahmodu Idris
ahmodu33@gmail.com
Physical and Life Science Department, National Space Research and Development Agency (NASRDA), F.C.T, Abuja, Nigeria.

1700. https://doi.org/10.1111/1556-4029.13819

[13] Goudsmit, H., Gunther, M., & Kerwin, J. (2016). *Organic gunshot residues: Identification and validation from forensic perspectives*. Analytical and Bioanalytical Chemistry, 408(11), 2935–2946. https://doi.org/10.1007/s00216-016-9757-2

[14] Castellanos, M. A., Fiebelkorn, K. R., & Valencia, J. (2016). *Advances in the analysis of gunshot residue: The significance of elemental composition in forensic science*. Forensic Chemistry, 2, 48–56. https://doi.org/10.1016/j.forechem.2016.06.003

[15] Sasu, N. (2024). *Challenges and strategies in gun crime prevention: Insights from recent trends in Nigeria*. Journal of Criminal Justice Studies, 22(3), 45–61.

[16] Ali, A., Geisbert, T. W., & Ainsworth, T. (2016). *The characterization of gunshot residues recovered from shooting incidents: A case study*. Forensic Science International, 265, 99–105. https://doi.org/10.1016/j.forsciint.2016.04.028.

Corresponding author: Ahmodu Idris
ahmodu33@gmail.com
Physical and Life Science Department, National Space Research and Development Agency (NASRDA), F.C.T, Abuja, Nigeria.