GRAND ACADEMIC PORTAL
RESEARCH JOURNALS

GAP INDIAN JOURNAL
OF FORENSICS AND BEHAVIOURAL SCIENCES
(ISSN – 2582-8177)
Globally peer-reviewed and open access journal.

EXPLOSIVE DEVICE RECONSTRUCTION THROUGH CHEMICAL AND TRACE EVIDENCE ANALYSIS: A HOMICIDE CASE INVESTIGATION

D Kumar*

*Scientist-B (Explosives), Central Forensic Science Laboratory, Pune - 410507,
Directorate of Forensic Science Services, Ministry of Home Affairs, Government of India
*dkumar.cfsl@gmail.com , ORCID iD : 0009-0009-6555-4657

Abstract

Post-blast investigations of improvised explosive devices (IEDs) represent one of the most demanding challenges in forensic science because of the destructive nature of explosions, which often results in extensive fragmentation, dispersal, and degradation of residues. In addition, environmental contamination, delayed recovery of evidence, and biological decomposition further complicate the identification of explosive constituents. This case report describes a homicide in which a homemade explosive (HME) device was detonated in an agricultural field, leading to the death of the victim. The forensic investigation was particularly complex, as the exhibits, including soil and debris samples, metallic fragments, jute thread, stone chips, the victim's clothing, and thermally altered portions of skin were collected and submitted for analysis five months after the incident. By this time, the exhibits had been exposed to weathering, biological infestation, and advanced decomposition, conditions that typically hinder the recovery of probative explosive residues. To overcome these challenges, a comprehensive sequential extraction protocol was adopted using ether, acetone, water, sodium hydroxide, and pyridine, enabling the recovery of both organic and inorganic constituents. These extracts were analyzed using complementary approaches, including classical chemical spot tests, thin-layer chromatography (TLC), and Fourier-transform infrared spectroscopy (FTIR). The results consistently confirmed the presence of potassium nitrate, ammonium nitrate, metallic aluminium, and elemental sulphur, while excluding the presence of high explosives such as RDX, TNT, PETN, or ANFO-type mixtures involving diesel fuel. The combined chemical and instrumental findings strongly supported the use of a nitrate-based low explosive formulation augmented with aluminium and sulphur to enhance sensitivity and combustion. Physical evidence, including metallic container fragments, stone chips, and remnants of jute thread, indicated that the device was configured as a fragmentation-oriented IED intended to maximize lethality through the dispersal of shrapnel. Despite the adverse conditions of the exhibits, including maggot-infested clothing and thermally altered biological tissue, the systematic application of multi-step extractions and confirmatory techniques enabled the robust identification of explosive residues. These results not only provided critical insights into the design and functioning of the device but also corroborated witness accounts and supported the reconstruction of the crime. This investigation demonstrates the resilience and forensic value of combining chemical testing, TLC, and FTIR in post-blast casework, even under conditions of advanced degradation and delayed submission, thereby strengthening both investigative leads and prosecutorial outcomes in homicide cases involving the use of improvised explosives.

Key Points

- *Demonstrates successful residue detection in a homicide case despite* ***five-month delay and severe sample degradation****.*
- *Confirms* ***nitrate-based homemade explosive (HME)*** *containing potassium nitrate, ammonium nitrate, aluminium, and sulphur.*
- *Excludes the presence of* ***high explosives and ANFO-type formulations****.*
- *Reveals a* ***fragmentation-oriented IED design*** *incorporating metallic fragments, stone chips, and jute thread.*
- *Highlights the* ***forensic value of sequential extraction and multi-technique analysis*** *in challenging post-blast scenarios.*

Keywords*: Post-Blast analysis, Homemade IED, Homicide investigation, Explosive residues, Forensic Trace evidence.*

INTRODUCTION

Explosive-related homicides are among the most complex cases in forensic science, largely because of the destructive nature of blast events and the consequent fragmentation and dispersion of physical evidence. Post-blast environments often contain commingled debris, vaporized or thermally altered residues, and trace particulates that may be present in minute quantities and subject to rapid environmental degradation [13, 18].

The recovery, preservation, and accurate analysis of these traces are critical for reconstructing the sequence of events, determining the type and origin of the explosive used, and establishing evidentiary links between the device, the scene, and potential suspects [15]. Achieving this requires a multidisciplinary approach, combining systematic scene processing, chemical characterization, and trace evidence examination [16]. Recent advances in analytical techniques, including Thin Layer Chromatography (TLC), Fourier Transform Infrared Spectroscopy (FTIR), and other spectrometric and chromatographic methods, have significantly enhanced the detection sensitivity and specificity for explosive residues, even in complex post-blast matrices [14, 17]. This study applies such a combined forensic methodology to a fatal case involving a Homemade Explosives (HME) type Improvised Explosive Device (IED), demonstrating the practical challenges, analytical strategies, and investigative value of integrated chemical and trace evidence analysis in post-blast homicide investigations.

CASE BACKGROUND

On the day of the incident, the victim went to the field for cultivation. The suspect, along with others surrounded the victim with deadly weapons and bombs. When the victim tried to escape, they threw bombs by targeting the victim. The victim was grievously injured on his right hand and ribs, and later died.

Local Police with Bomb disposal squad rushed to the crime scene and searched the area for possible clues. They found unexploded live bombs and debris from exploded bombs. The live bombs were disposed of by the bomb disposal squad in a controlled manner. The exhibits collected from the place of occurrence were properly packed, sealed and sent to the laboratory for chemical analysis to identify the explosive residues in the debris. A case was registered against the suspects and four persons were arrested.

MATERIALS AND METHODS

Evidence Collection

The crime scene was secured, and thorough documentation was conducted. Soil with blood stain and control soil samples were collected systematically from multiple points around the blast epicenter. Suspected explosive fragments of the exploded IED including bundle of Jute thread, Stone chips, broken pieces of metallic containers were recovered and carefully packaged to prevent contamination or loss of residue. Victim's upper & lower clothing and a portion of his burned skin (without preservation) were also taken to detect trace explosive materials. These are given in Figure- 1 to 3.

Fig 1. Burned Skin of the victim

Fig 2. Dress of the Victim

Fig 3. Broken metallic container, Jute thread and Stone chips

Exhibits preparation

The exhibits were received by the laboratory in six different parcels after five months of the incident occurred. The Soil sample were sent to the Biology division for identification of the blood stain and transferred to the Explosive Division for identification of trace elements. The Jute thread, Stone chips, broken pieces of metallic containers, soil samples and skin of the deceased were properly extracted by Ether, Acetone, Water, Sodium Hydroxide and Pyridine for identification of the both In-Organic and Organic Explosive traces. The dresses of the victim were in wet condition with formation of maggots. Hence, water extract taken first and followed by other extracts.

Chemicals and Solvents

Diethyl Ether was obtained from Finar, Acetone (AR) was obtained from Advent Chembio Pvt. Ltd, Sodium Hydroxide, and Pyridine was obtained from SRL. Demineralized (DM) water procured from Labogen Fine Chem Industry, Ludhiana was used for Water and Alkali extraction. Whatman-42 filter paper was used for its filtration. Allpure Nylon Syringe filter (pore size 0.22 µm) was procured from Membrane Solutions was used for filtration of Ether and Acetone extracts. [19, 20]

Silica gel 60G F254 Plates with 200 micrometer thickness and Size 20 x 20 cm were used for Thin Layer Chromatography (TLC) analysis. Chloroform, Acetone, Toluene and Cyclo hexane used for the test.

Ether Extraction

The samples were treated with ether, filtered using syringe filter to remove any solid impurities, the filtrate was collected in a 100ml beaker and concentrated upto 1ml by evaporation in the room temperature. The filtrate was analyzed in the FTIR-ATR for Diesel oil for the identification of Ammonium Nitrate Fuel Oil (ANFO).

Acetone Extraction

The same samples were treated with acetone after complete evaporation of the ether and filtered using the same syringe filter to remove any solid impurities, the filtrate was collected in the same 100ml beaker and concentrated upto 1ml by evaporation in the room temperature. The filtrate was analyzed by chemical examination, TLC and FTIR with the standard for the identification of Organic Explosives, such as, PETN, TNT, RDX.

Water Extraction

The same samples were treated with hot distilled water after complete evaporation of the acetone and filtered using the Whatman-42 filter paper to remove any solid impurities, the filtrate was collected in the same 100ml beaker and concentrated upto 10ml. The filtrate was analyzed for In-organic Explosive ions like, Sodium, Potassium, Ammonium, Nitrate, etc. After the Chemical Examination, the remaining extract allowed to dry and the dried sample was analyzed in the FTIR.

Alkali Extraction

The same samples were treated with 2N Sodium Hydroxide, filtered using the same Whatman-42 filter paper to remove any solid impurities, the filtrate was collected in the same 100ml beaker and concentrated upto 10ml. The extract was tested for metallic Aluminium, Arsenic and Sulphide ions.

Pyridine Extraction

The same samples were treated with Pyridine, filtered using the same Whatman-42 filter paper to remove any solid impurities, the filtrate was collected in the same 100ml beaker and concentrated upto 1ml. Taken in a small test tube, slightly boiled and a drop of 2N Sodium Hydroxide was added to identify Elemental Sulphur.

Thin Layer Chromatography

Pre-coated TLC plates were activated by placing them in an air oven at 110°C for 30 minutes. One hundred ml of solvent [chloroform : acetone (1:1) and toluene : cyclohexane (7:3)] was taken in two different developing chambers (for 20 × 20 cm TLC plates), covered with a lid, and allowed to saturate for at least 30 minutes. The concentrated acetone extract of each sample was spotted on the pre-coated TLC plate along with reference standards of high explosives, leaving 2 cm from one edge at the bottom of the TLC plate and maintaining a minimum distance of 1.5 cm between two spots. The TLC plate was placed vertically in the developing chamber and allowed to develop until the solvent front rose to 10 cm from the spots by capillary action. After completion, the plate was removed and left at room temperature for the eluent to evaporate.

The TLC plate was developed by spraying with 5% diphenylamine (DPA) in 95% ethanol, and the colour produced was noted. The plate was then placed under UV light (254 nm) to observe fluorescence and subsequently sprayed with concentrated sulphuric acid, with the resulting colours recorded. The colours were compared with the Rf values given in Table 1.

Table 1 - Rf values with various solvents and colour of spot for Organic Explosives

Compound	Colour Development				Rf Values in Different Solvent Systems.			
	DPA	UV light	Sulphuric Acid	Griess Reagent	Trichloro-ethylene : Acetone (4:1)	Chloro-form : Acetone (1:1)	Toluene : Cyclo- hexane (7:3)	Toluene : Ethyl -acetate (9:1)
NG	No colour	Gray to Green	Blue-gray	Pink	0.47	---	0.42	0.66
RDX	No colour	Gray	Blue-gray	Red	0.15	0.47	0.03	0.13
PETN	No colour	Gray to Green	Blue-green	Red	0.55	0.69	0.45	0.78
TNT	Orange Brown	Orange Brown	Colour fades	Brown	0.59	---	0.57	0.88
TETRYL	Brown	Brown	Yellow to	Red	0.40	0.66	0.25	0.61

			Blue-gray					
HMX	No colour	No colour	No colour	Red	---	0.40	---	---

Fourier transform infrared spectroscopy (FTIR)

The Ether extract, Acetone extract and dried samples of the water extract were examined in the Thermo Fisher Scientific Nicolet iS20 FTIR spectrometer instrument, which equipped with an IR source, an attenuated total reflectance (ATR) accessory, a DTGS detector and KBr beam splitter from Thermo Fisher Scientific. The instrument was operated at resolution of 4.000 between wavenumber 4000 cm-1 to 400 cm-1. The analysis was done by scanning background and sample using Thermo Scientific OMNIC software. The sample was scanned for 64 times and a characteristic spectrum was obtained. The spectrum was searched using correlation search type in the libraries of the instrument to identify the sample.[19, 20]

CHALLENGES IN THE ANALYSIS OF EXHIBITS

The victim’s clothing was wet, with maggot formation, and it was not possible to take swabs from the charred parts or cut a portion. It was treated with ether, and the ether and water extracts were separated using a separating funnel and filtered. In the same manner, the clothing was treated with acetone, and the acetone and water extracts were separated and filtered. Since the volume of ether, acetone, and water filtrates was high, they were carefully concentrated at room temperature as well as through boiling.

The skin sample was in a shrunken condition and was thoroughly mixed with ether and stirred with a glass rod for complete recovery of both high and low explosives. The extract was filtered and analyzed. The same procedure was followed for acetone, water, sodium hydroxide, and pyridine extractions.

Observations

Chemical Examinations

There was no significant presence of High Explosives observed in the Acetone Extract. The Low Explosives identified in the Water, Alkali and Pyridine extracts are given in the Table-2.

Table 2. Observations of the Chemical Examinations

Sl.No	Chemical Test	Target Ion/Analyte	Observation
1	Silver Nitrate	Chloride	Present
2	Griess Test	Nitrite	Present
3	Griess reagent + Zn dust	Nitrate	Present
4	Aniline sulphate	Chlorate	Absent
5	Methylene blue indicator	Perchlorate	Absent
6	Barium chloride	Sulphate	Present
7	Zinc Uranyl Acetate	Sodium	Absent
8	Sodium Cobaltinitrate	Potassium	Present
9	Nessler’s reagent	Ammonium	Present
10	Magneson-I	Magnesium	Absent
11	Sodium Rhodizonate	Barium, Calcium, Strontium	Absent
12	Sodium Nitroprusside	Sulphide (NaOH Extract)	Absent
13	Alizarine-S	Metallic Aluminium (NaOH Extract)	Present
14	Gutzeit’s Test	Arsenic (NaOH Extract)	Absent
15	Pyridine + NaOH	Elemental Sulphur	Present

Except for the control soil, all the exhibits gave positive results for low explosives.

TLC Analysis

No specific High Explosives were observed in the TLC analysis of Acetone Extract.

FTIR Analysis

No significant High Explosives and Diesel Fuel present in the FTIR analysis of Acetone Extract and Ether Extract. However, Potassium Nitrate and Ammonium Nitrate (Low Explosives) were identified in the dried sample of Water Extract. The FTIR spectrum were given in the Figure-4 and Figure-5.

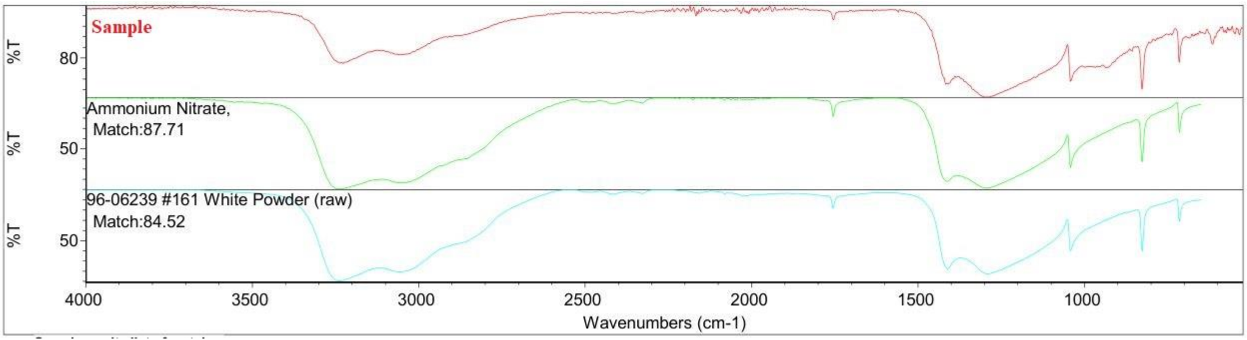

Fig 4. FTIR spectrum of the sample (top) and its library match (bottom)

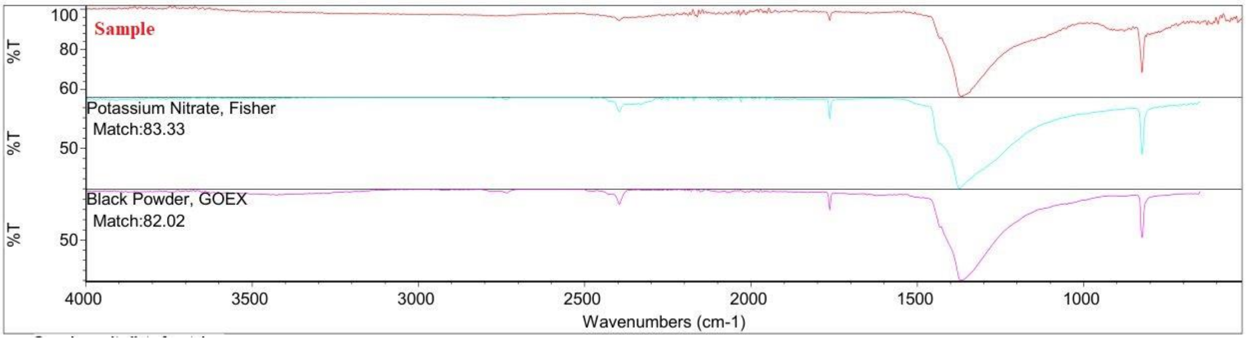

Fig.5. FTIR spectrum of the sample (top) and its library match (bottom)

RESULTS AND DISCUSSION

The forensic examination of the exhibits revealed the predominance of low explosive residues, with no detectable high explosive components in either acetone or ether extracts. Chemical analysis confirmed the presence of nitrate, nitrite, chloride, sulphate, potassium, ammonium, metallic aluminium, and elemental sulphur in the water, alkali, and pyridine extracts from multiple exhibits, excluding the control soil sample. These findings are consistent with the formulation of improvised low explosive mixtures, particularly those incorporating potassium nitrate or ammonium nitrate as oxidizers, metallic aluminium as a fuel sensitizer, and sulphur as an additional combustible component [1, 4, 9]. The cumulative observation of the ions detection by the Chemical Examination is given in the Fig-6.

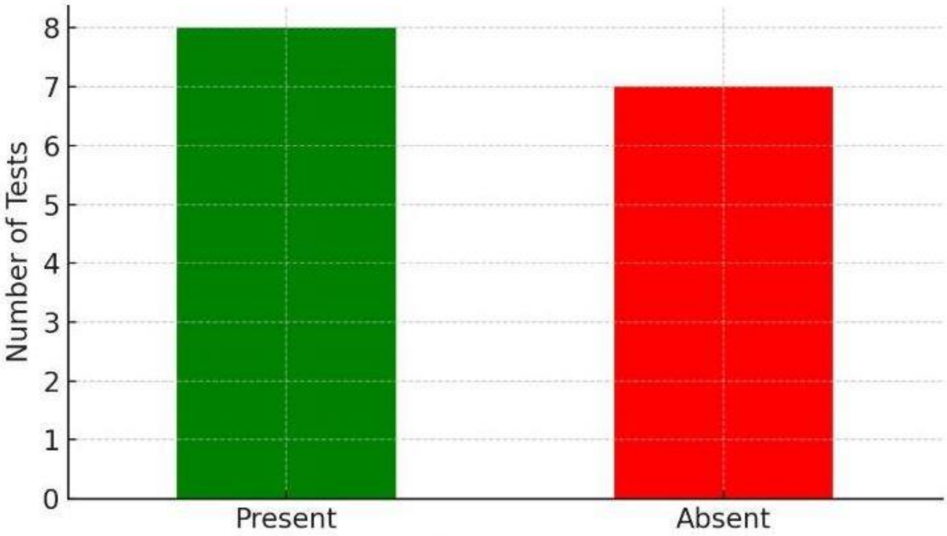

Fig.6. Observation of Ions by the Chemical Examination

TLC analysis did not yield detectable high explosive signatures, further supporting the conclusion that the device employed was based on low explosive chemistry. FTIR examination corroborated the presence of potassium nitrate and ammonium nitrate in water extracts, with distinct absorption bands corresponding to nitrate functional groups, while no diesel fuel or organic high explosive peaks were identified. This analytical outcome rules out ANFO-type explosives, despite the detection of nitrate salts [2, 5, 10].

The combined evidence profile aligns with common homemade explosive (HME) formulations, such as mixtures of potassium nitrate, sulphur, and aluminium powder, which are known to produce significant blast effects in confined or semi-confined configurations [3, 8]. The recovery of metallic container fragments, stone chips, and jute thread suggests the use of a fragmentation-oriented improvised explosive device (IED), designed to increase lethality through the dispersion of shrapnel [6, 11].

An important aspect of this investigation was the challenging condition of the exhibits. The victim's clothing was received in a decomposed state with maggot infestation and retained moisture, while the skin sample was shrunken and thermally altered. Despite these adverse preservation conditions and the five-month delay between incident and laboratory receipt, careful sequential solvent extraction enabled recovery of detectable residues. This underlines the robustness of the applied extraction and analytical protocols in recovering forensic evidence even under conditions of significant degradation [7, 9].

From an investigative standpoint, the analytical confirmation of specific chemical constituents provided critical information for reconstructing the device composition and corroborating witness accounts of the blast mechanism. The absence of high explosive residues also has legal and operational implications, narrowing the scope of possible explosive precursors and focusing the investigation towards locally accessible materials [1, 4, 12].

CONCLUSION

This case study demonstrates the practical challenges and scientific strategies in post-blast forensic analysis of a homicide involving an improvised low explosive device. The integrated use of chemical testing, TLC, and FTIR enabled the identification of potassium nitrate, ammonium nitrate, metallic aluminium, and sulphur, establishing the presence of a nitrate-based HME formulation [2, 4, 10]. The absence of high explosives and diesel fuel in the recovered residues indicated the use of a low explosive mixture, likely combined with shrapnel materials to enhance lethality [3, 8].

The successful recovery of explosive residues from highly degraded exhibits, including decomposed clothing and thermally altered human tissue, illustrates the effectiveness of sequential solvent extraction in post-blast investigations [7, 9]. The correlation of analytical results with physical evidence such as metallic fragments, stone chips, and jute thread provided a comprehensive reconstruction of the device design and operational intent [6, 11].

Overall, the findings underscore the importance of systematic evidence collection, appropriate extraction protocols, and multi-technique analytical approaches in overcoming the limitations posed by environmental degradation and delayed evidence submission [1, 4, 12]. Such methodologies are vital in supporting both investigative leads and prosecutorial outcomes in explosive-related homicide cases.

ABBREVIATIONS

IED	Improvised Explosive Device
HME	Homemade Explosives
TLC	Thin Layer Chromatography
FTIR	Fourier Transform Infrared Spectroscopy
AR	Analytical Reagent
DM	De-Mineralized
ATR	Attenuated Total Reflectance
ANFO	Ammonium Nitrate Fuel Oil
PETN	Penta Erythritol Tetra Nitrate
TNT	Tri Nitro Toluene
RDX	Research Department Explosive/ Royal Demolition Explosive
NG	Nitro Glycerin
TETRYL	*Trinitrophenylmethylnitramine*
HMX	High Melting eXplosive - Octogen
DPA	Di Phenyl Amine
UV	Ultra Violet
DTGS	Deuterated Tri Glycine Sulfate
IR	Infra Red
NaOH	Sodium Hydroxide

ACKNOWLEDGEMENTS

I would like to thank the Director of Central Forensic Science Laboratory, Pune, for providing necessary support and infrastructure for conducting this work.

COMPLAINT WITH ETHICAL STANDARDS

Ethical approval was not applicable, as the forensic examination (including the related court deposition) was conducted as part of routine medico-legal duty and had already been completed prior to manuscript preparation. No additional research interventions were undertaken, in accordance with COPE-based ethical guidance.

CONSENT FOR PUBLICATION

Consent for publication was waived, as the case involves a deceased individual and all identifying details have been anonymized. This approach is consistent with institutional policy, journal requirements, and COPE-based ethical guidance.

FUNDING

The author received no specific funding for this work.

CONFLICT OF INTEREST

The author has no conflict of interest.

DATA AVAILABILITY STATEMENT

The author declares that the data supporting the findings of this study are available within the paper. Should any raw data files be needed in another format, they are available from the author upon reasonable request.

REFERENCES

[1] Yinon, J. *Forensic and Environmental Detection of Explosives*. CRC Press, 1999.
[2] Beveridge, A. *Forensic Investigation of Explosions*. 2nd ed., CRC Press, 2011.
[3] Kumar, A., Sharma, R., & Singh, S. “Analysis of low explosive residues from post-blast debris.” *Forensic Sci Int*, 2008; 177(1): 42–49.
[4] Yinon, J., & Zitrin, S. *Modern Methods and Applications in Analysis of Explosives*. John Wiley & Sons, 1993.
[5] Bell, S., et al. “Forensic applications of FTIR spectroscopy.” *Forensic Sci Rev*, 2016; 28(2): 145–166.
[6] Gross, S.R., et al. “Fragmentation patterns in IED-related fatalities.” *J Forensic Sci*, 2012; 57(5): 1235–1241.
[7] Douse, J.M. “Sampling and analysis of explosives residues in post-blast scenes.” *J Energetic Materials*, 1985; 3(1): 1–25.
[8] Akhavan, J. *The Chemistry of Explosives*. 3rd ed., RSC Publishing, 2011.
[9] Jenkins, T.F., et al. “Environmental degradation of explosive residues.” *Chemosphere*, 2006; 63(9): 1460–1471.
[10] Yinon, J. “Detection of explosives by spectroscopic techniques.” *Talanta*, 2002; 54(3): 501–514.
[11] Raza, M., et al. “Forensic reconstruction of improvised explosive devices.” *Defence Science Journal*, 2015; 65(4): 300–306.
[12] Gardos, M.N., & Schubert, H. “Forensic exploitation of explosive materials.” *Propellants, Explosives, Pyrotechnics*, 1990; 15(2): 51–56.
[13] Beveridge, A. D. (2021). *Forensic Investigation of Explosions*. CRC Press.
[14] García-Ruiz, C., Torre, M., & García, J. (2013). Analytical techniques in post-blast investigation: A review. *TrAC Trends in Analytical Chemistry*, 54, 36–43.
[15] Murray, K. K., Boyd, R. K., Eberlin, M. N., Langley, G. J., Li, L., & Naito, Y. (2018). Definitions of terms relating to mass spectrometry (IUPAC Recommendations 2013). *Pure and Applied Chemistry*, 85(7), 1515–1609.
[16] Ruffell, A., & McKinley, J. (2005). Forensic geomorphology. *Geomorphology*, 67(1–2), 3–12.
[17] Sigman, M. E., Clark, C. D., & Williams, M. R. (2014). Forensic analysis of explosives residues. *Analytical and Bioanalytical Chemistry*, 406(21), 5331–5345.
[18] Yinon, J., & Zitrin, S. (1996). *Modern Methods and Applications in Analysis of Explosives*. John Wiley & Sons.
[19] Kumar.D, Prajakta. U.K. Optimizing Forensic Detection of Explosive Substances: Extended Column Analysis of TNT. International Journal for Research in Applied Science & Engineering Technology (IJRASET). https://doi.org/10.22214/ijraset.2025.71458.
[20] Kumar.D, Prajakta. U.K. Thermal Decomposition Approach for PETN Detection in Improvised Explosive Devices. International Journal of Innovative Research in Technology (IJIRT). May 2025 | IJIRT | Volume 11 Issue 12 | ISSN: 2349-6002. https://doi.org/10.64643/IJIRTV12I3-179451-457
[21] D. Kumar. Explosive Device Reconstruction through Chemical and Trace Evidence Analysis: A Homicide Case Investigation, 17 August 2025, PREPRINT (Version 1), Research Square [https://doi.org/10.21203/rs.3.rs-

7365009/v1].