

COMPOSITION OF EXPLOSIVE AND THEIR EFFECT AT DIFFERENT
CRIME SCENEAfshan Maqbool¹, Noor UL Aien^{2*}, Azka Kanwal², Minahil Ahsan², Azka Khalil²¹Akbar Institute of Medical Sciences, Bahawalpur, Pakistan²Department of Forensic Science, The Islamia University of Bahawalpur, PakistanSubmitted 9th July 2023, Accepted 12th February 2024, Published 30th April 2024

ABSTRACT

An important area of forensic science called "explosive trace evidence analysis" is concerned with identifying and interpreting minute explosive remnants found at crime scenes and during security screening. In criminal investigations, counterterrorism operations, and safety inspections, the identification and analysis of these trace chemicals are crucial. X-ray diffraction, gas chromatography-mass spectrometry, Fourier transform infrared spectroscopy, and ion mobility spectrometry are just a few of the approaches and techniques used in this paper's thorough discussion of explosive trace evidence examination. With the use of these techniques, forensic professionals are able to precisely identify and classify certain explosive compounds, assisting in the identification of the origins of explosives and gaining a better knowledge of their potential dangers. It emphasizes the value of expert testimony in court processes as well as the function of forensic specialists in the gathering, preservation, and analysis of evidence. The paper also emphasizes the significance of ongoing study and technological development in the area, as well as the potential for future advancements in nanotechnology, artificial intelligence, and cooperative efforts to improve the efficacy and efficiency of explosive trace evidence analysis. Explosive trace evidence analysis continues to be vital in preserving public safety and security by successfully thwarting explosives-related crime and terrorism thanks to continual developments and breakthroughs.

Keywords: Nanotechnology X-ray diffraction, PETN, Explosive in crimes scene, TNT, RDX.

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INTRODUCTION

An explosive is a substance or material that undergoes a quick chemical reaction, frequently followed by the release of significant amounts of energy in the form of heat, light, sound, and gases. This quick release of energy produces an explosive force that has a strong and violent impact. The term "explosive trace evidence" refers to the minuscule fragments or remains of explosive materials that might be discovered at a crime scene or on objects connected to explosives. These minuscule residues, which may be particles, gases, or chemical substances, are left behind when explosive chemicals are detonated or handled. Due to their potential for abuse and the serious threats they represent to public safety, explosives are highly regulated and controlled chemicals. Mining, building, military operations, and research are just a few of their legitimate uses. Strict regulations on their production, sale, transit, and possession are in place as a result of their usage in illegal operations or terrorist attacks. Explosives are significant because of the wide range of industries they are used in, from the military

and defense to business and research. The following significant factors underline the significance of explosives: Military and defense: Explosives are used in a variety of military activities, including the manufacture of munitions for bombs, missiles, and artillery rounds. They are utilized in battle scenarios to eliminate hostile objectives, penetrate defenses, and gain strategic benefits. Explosives are crucial for national defense and ensuring a country's security. Explosives are commonly employed in mining operations to break up and recover precious minerals, ores, and rocks from the ground. Controlled explosive blasting techniques enable effective mining activities, which are required for resource extraction and numerous building projects such as tunneling and excavation [1, 2]. Demolition and Controlled Demolition: In demolition operations, controlled explosives are used to safely and effectively bring down structures such as buildings, bridges, and other infrastructure. Controlled demolition contributes to urban revitalization by removing unsafe structures

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and preparing spaces for reconstruction. Explosives are employed as propellants in ammunition and rockets for military and civilian uses. They provide the required force for projectiles to travel at great *speeds* and across vast distances. Explosives are the cornerstone of pyrotechnics, which are used to produce spectacular fireworks displays for amusement at celebrations, events, and festivals. Explosives are important instruments for scientific study and testing, notably in disciplines such as ballistics, materials science, shockwave physics, and aeronautical engineering. They give useful information on the behavior of materials under harsh circumstances. Explosives are employed in the oil and gas sector for seismic exploration, which is a way of detecting probable oil and gas deposits by creating shockwaves to assess subsurface geological formations. Trace explosives are critical in criminal investigations for identifying bomb-makers, connecting individuals to explosive devices, and recreating the events leading up to an investigation. Techniques used for detection of explosives include, Gas chromatography and mass spectrometer, X-ray diffraction, Thin film sensor for explosives detection, hydrogen kit for TNT detection, and Raman spectroscopy for conducting gold and palladium. Many injuries resulting from explosives were identified. We talked about arriving at the crime scene with a strategy in place, based on the open and close system explosive. The plan's purpose is to gather evidence for the judge and jury to consider. This aids law enforcement authorities in the resolution of cases and the prevention of future instances. The relevance of explosives comes with severe hazards despite its many useful applications. Due to the potentially catastrophic effects of improper handling, unauthorized usage, or accidental explosion, their use and handling are governed by stringent laws and safety procedures [3-5].

TYPES OF EXPLOSIVES

High Explosives are classified into primary high explosives and Secondary high explosives. Primary high explosives, These are incredibly sensitive and serve as detonators or initiators for other explosives. They start the detonation process with a little stimulation like heat, stress, or friction. Lead azide and mercury fulminate are two examples. Secondary high explosives, These explosives are generally stable and require a strong shock or heat to detonate. They are often utilized as the primary charge in a variety of applications, such as military ammunition, industrial

blasting, and commercial explosives. TNT (trinitrotoluene), RDX (cyclotrimethylene trinitramine), HMX (cyclotetramethylene tetranitramine), and PETN (pentaerythritol tetranitrate) are a few examples. Low Explosives, burn at a slower rate and cause deflagration rather than explosion. They are often utilized in applications requiring a regulated, constant delivery of energy. Low explosives include blackpowder (a combination of potassium nitrate, charcoal, and sulfur), gunpowder, and several propellants used in weapons and rockets. Blasting agents are fuel-and-oxidizer mixes used for controlled blasting in mining, building, and quarrying. They are less sensitive than primary and secondary high explosives and are controlled separately due to their decreased potential for abuse. Blasting agents include ammonium nitrate fuel oil (ANFO) and emulsions. Propellants made from smokeless powders are employed in guns, artillery, and tiny rockets. They burn quickly and emit little visible smoke, making them appropriate for both military and civilian purposes. Smokeless powders are categorized as either double-base (nitrocellulose-based) or single-base (nitrocellulose and nitroglycerin-based). IEDs are explosives built at home by mixing various chemicals and materials. They are frequently utilized in terrorist and insurgent actions [6].

RESIDUES

Explosive residues are the tiny leftovers or traces of explosives left behind following the handling, explosion, or usage of explosive materials. These residues can be detected on a variety of surfaces, items, or humans related with explosives. The sorts of leftovers produced are determined on the explosive used and the circumstances surrounding its usage. Here are some examples of common forms of explosive residues: Nitrate compounds are a typical form of explosive residue that may be found in a variety of explosives. Ammonium nitrate and potassium nitrate, for example, leave behind nitrate residues that may be discovered and examined. Because of their nature, inorganic explosives such as black powder may leave behind distinctive inorganic residues. Black powder, for example, comprises potassium nitrate, charcoal, and sulfur, all of which leave residues behind. The vicinity of explosives being carried or stored can also produce explosive vapors or fumes. The explosive that was used can be determined by analyzing these vaporous remains.

Table 1: Types of explosive present at crime scene and their techniques for identification purposes.

Explosive	Low explosive	High explosives
	Nitrocellulose Nitroguanidine Black Powder	Ammonium nitrate blasting agents and 2,4,6-trinitrotoluene (TNT).
	Charcoal Potassium nitrate Sulfur	
Techniques for detection	Marquis test Scott test Modified grief test Dille-koppanyi test	Gas chromatography, Raman spectrophotometer ICVD Hydrogel kit, FTIR

PLAN OF ARRIVAL IN EXPLOSIVE SCENE

While assessing the scene, it's critical to ascertain the plan. The initial step is "examining the crime scene on location." The deceased person's body, or portions of it, an organ, or tissue are then transported to a lab for autopsy.

Next, attempting to ascertain whether the explosion was caused by a terrorist strike, a domestic incident, a work-related incident, or something having to do with heavy transportation. Initially, we comprehended the two rationales for the on-site scene investigation. The deceased victim or perpetrator" (particularly in cases of suicide bombers). Secondly, "aids in resolving any possible explosion mysteries [7].

Next, we separated this on-site scene analysis into two groups. When a bombing occurs in a close system, the pressure waves and mechanical energy released by the device not only injure people directly but also have an impact on surrounding homes and buildings. When a bomb goes off in an open space, like a rural area or an outlying area, the pressure waves from the explosion cause some dead victims to fall into a distant place. As a forensic scientist, you investigate scenes in public spaces for a variety of reasons, such as weather patterns, the presence of nearby predators, the natural decomposition of a dead corpse, or biological evidence. Therefore, we can divide an open region for inquiry into smaller subareas, and it was the responsibility of each investigator to examine their area for a portion of the dead body or any other physical evidence, arson etc. When we first arrive at a site, we examine the security assessment. At the same time, the police set up a second border line a few meters in front of the scene to keep predators out and prevent them from interfering with the investigators' job gathering evidence. For the benefit of the "judge, jury, and any future investigators reviewing the case, an accurate photograph of the scene" that shows the victims' visible injuries in relation to the location of their bodies and the distance from the explosive device is essential [8].

COLLECTION AND PRESERVATION OF EXPLOSIVES

To protect investigators' safety and the integrity of the evidence, collecting and storing explosives and their remnants calls for cautious handling and adherence to established processes. The following are the essential procedures for gathering and preserving explosives: Safety precautions, Before approaching the location, make sure it's safe and clear of any potential risks or secondary devices. To reduce the danger of contamination, use proper personal protective equipment (PPE) such as gloves, goggles, and protective clothes. Secure the scene, Create a protective perimeter around the explosion scene to prevent illegal entry and evidence contamination. Limit the amount of people permitted in the area to protect the integrity of the evidence. Documentation, Photographs, sketching, and written notes should be used to adequately document the

situation. This includes the location and position of any explosive devices as well as any evidence relating to them. Marking and Labeling, any explosive-related evidence should be clearly marked and labeled to guarantee appropriate identification and chain of custody. Collection of residues, Collect explosive remnants with clean, dry instruments and containers. Avoid utilizing tools or containers that might introduce infection. Depending on the type of the residues and the surface they are discovered on, several collecting procedures, such as swabbing, scraping, and vacuuming, may be used. Packaging, to package explosive remnants, use airtight and non-reactive containers. Glass, metal, or plastic containers with secure sealing are widely utilized. To prevent cross-contamination, package each sample separately. Document and mark each package with pertinent information, such as the location, date, time, and name of the individual collecting the evidence. Chain of custody, Maintain a rigorous chain of custody for all gathered evidence, recording each transfer or handling of the evidence from the crime scene to the laboratory. This maintains the evidence's integrity and gives a clear record of who had custody of the evidence at any given moment. Transport and Storage, Use secure and approved transportation ways to get the gathered evidence to the lab or storage location. To avoid deterioration or contamination, keep the evidence in a controlled setting. Laboratory Analysis, The explosives and residues that have been gathered will undergo a thorough study by forensic experts in a specialized facility to ascertain their kind, composition, and other pertinent details [8, 9].

ANALYSIS TECHNIQUES OF EXPLOSIVES

Gas Chromatography and Mass spectrometry

Gas chromatography, the gaseous or vaporized sample containing the explosives is delivered into the GC system. The sample is inserted into the GC column, which is a long, coiled tube covered with a stationary phase. The components of the sample are separated depending on their affinity for the stationary phase and volatility. A heated carrier gas (typically helium or nitrogen) transports the sample along the column, and various chemicals elute at different periods, resulting in their separation. Mass spectrometry, Ionization occurs as the separated chemicals enter the mass spectrometer after leaving the GC column. Electron impact and chemical ionization are two frequently used ionization methods. Fragmentation: As a result of ionization, molecules fragment into smaller pieces. The pattern of fragmentation is unique to the particular substance under investigation. The mass spectrometer uses its mass-to-charge ratio (m/z) detector to identify the ions created during ionization. A depiction of ion abundance against m/z is produced by the detector called a mass spectrum [10].

Raman Spectrometry

Raman spectroscopy has been broadly used in forensic labs for the detection of explosive

compounds. For example, if a criminal offense related to explosives takes place in a market, first responders may also package deal the objects and ship them to the laboratory for analysis. However, this method can be time-consuming and may result in pattern infection at some point of coping with. Although Raman spectroscopy isn't always used as a confirmatory test in court, benchtop Raman spectrometers can be a useful resource in the fast detection of doubtlessly hazardous chemicals at the scene. Raman spectroscopy assists scientists in detecting chemicals that could have induced massive-scale destruction, such as AN, PETN, TNT, HMX, and RDX. These spectrometers are extremely sensitive and non-detrimental, allowing them to discover even hint amounts of samples without negative the evidence. Furthermore, they assist to reduce scientists' direct interaction with explosive compounds, thereby enhancing protection [11].

X-Ray Diffractions

A non-destructive analytical method for determining the crystalline structure of materials, including explosives, is X-ray diffraction (XRD). The foundation of X-ray diffractometric (XRD) is the idea that when X-rays are focused on a crystalline sample, they interact with the atoms in the crystal lattice and scatter at certain angles. The crystal structure is shown in great detail by the ensuing diffraction pattern, which enables material identification.

Thin Film Sensor (iCVD)

According to Tenhaeff et al. A selective polymer for explosive detection was prepared using a technique called reserve chemical vapor deposition (iCVD). Poly(4-vinylpyridine) was loaded into small microfabrication tubes. This polymer coating was then coated with conductive gold/palladium. As the polymer absorbed the target gas, it expanded, allowing contact between the conducting fibers [12-15].

Hydrogel Test Kit for Pre and Post Blastic Trinitrotoluene (TNT)

The PVA hydrogel test kit was powered by a combination of two ingredients: cryogenic treatment and chemical cross linking. We employ two separate chemicals for the process. We utilise EDGE for chemical cross-linking, and KOH is thought to be a superior colorimetric reagent. Entrapped KOH is liberated from the hydrogen matrix during a process, reacts with TNT, and produces a specific color that can be detected. These days, quantitative analysis can be obtained by using an iPhone to create a digital image colorimeter, which eliminates the necessity for spectrophotometric detection [16].

Fourier Transform Infrared Spectroscopy

Explosives may be identified and their chemical makeup can be characterized using the potent analytical technique known as Fourier Transform Infrared Spectroscopy (FTIR). Based on the idea that molecules absorb infrared light at certain wavelengths, each chemical compound has its own distinctive absorption bands. This is the fundamental premise of FTIR. In order to analyze explosives,

FTIR is employed as follows: Prepare a sample of a tiny sample of the potentially dangerous substance is gathered and prepared for examination. In order to enable infrared measurements, the sample is often crushed into a fine powder or flattened into a thin film. The sample is exposed to an infrared beam, which interacts with the sample's molecular structure to cause the absorption of particular infrared light frequencies. Utilization of Infrared Light the chemical bonds in the explosive molecules vibrate when infrared radiation flows through the sample and absorbs certain infrared light frequencies. The kind of atoms in the molecule and their arrangement dictate the particular frequencies that are absorbed. Finding and Fourier Transform. A detector gathers the transmitted or reflected infrared light from the sample, and the signal is then transformed into an interferogram. The interferogram is next put through a mathematical procedure called the Fourier Transform, which turns the time-domain data into a spectrum reflecting the strength of absorption as a function of wavenumbers. Data Evaluation, obtained FTIR spectrum is contrasted with reference spectra found in databases or libraries that are known to contain the spectra of different explosive compounds. The precise functional groups and molecular components of the explosive substance can be determined by comparing the absorption bands in the FTIR spectrum with those in the reference database [17].

In order to give useful information for criminal investigations, security operations, and legal actions, forensic analysis and interpretation of explosives entails the study, identification, and assessment of explosive materials and residues. Here is a summary of the main procedures in the forensic examination of explosives: Gathering of Evidence, the crime scene or probable sources are searched by forensic investigators for potential explosive materials and residues. To preserve the integrity of the evidence, the correct chain of custody procedures are followed. To find explosive residues and determine prospective areas of interest, preliminary screening tests may be carried out using colorimetric assays or portable devices like ion mobility spectrometry (IMS). Laboratory Analysis, More advanced laboratory methods, such as X-ray diffraction, nuclear magnetic resonance (NMR) spectroscopy, Fourier transform infrared spectroscopy, and gas chromatography-mass spectrometry (GC-MS), are used to the gathered evidence. These methods offer thorough information on the chemical make-up, molecular structure, and crystallinity of the explosive materials. The precise type of explosive used is determined by comparing the results of the laboratory examination to known reference samples of explosives. Occasionally, calibration curves and standard samples can be used to determine how much explosive material is contained in the sample. Post blast explosion-related occurrences, forensic investigation include examining blast remnants, explosive device components, and reconstructing the

explosive event in order to ascertain the type of explosion and its most likely cause. Reporting and Interpretation: The analytical data are interpreted by forensic specialists, who then outline their conclusions in a report. The report provides the identified explosive type, the analytical technique, and the degree of confidence in the identification. The report is written in a way that is appropriate for use in court and may contain expert evidence. Expert Testimony, In court, forensic specialists may be asked to testify as an expert witness, outlining their research methods and the importance of the evidence in the case. Criminal investigations, terrorism-related cases, and forensic intelligence collection all heavily rely on the forensic examination and interpretation of explosives. Law enforcement authorities may identify suspects, connect people to explosive devices, and recreate the sequence of events leading up to an explosion with the use of accurate and trustworthy analysis. The outcomes of forensic analysis are crucial in obtaining convictions and guaranteeing that justice is done [18].

INJURIES CAUSED BY EXPLOSIVES

When someone is hurt by blastic explosives, their injuries are not the same as in other situations. Here, we classified into four distinct groups.

It is brought on by blast waves propagating and striking the body directly. It is correlated with the wave's pressure and speed; the higher the wave, the greater the likelihood of injury. These occur most frequently when a person is near a bomb blast area. Secondary injury: in a missile attack, the explosive detonates into pieces or the victim's body sustains punctures, abrasions, and bruises [7]. Third-party wounds. Because of the limited range of gases released following an explosion, these kinds of injuries typically happen when a person is close to the blast trigger point. Traumatic hypoxia and the inhaling of poisonous gases are examples of quantitative injuries [12].

CHALLENGES AND LIMITATIONS

Explosives-related difficulties and restrictions cover a range of issues with reference to their production, handling, detection, and security. Here are some significant difficulties and restrictions related to explosives: Safety Risks: The main issue with explosives is the risk that they pose. Misuse, unintentional explosions, or poor storage can result in serious injuries, deaths, and property damage. Explosives can be used improperly for insurrection, terrorism, or criminal activity. For law enforcement and security organizations, the illicit usage and purchase of explosives present serious difficulties. Complexity of Detection: Due to their low metal content or camouflaged look, some explosives, especially homemade ones, might be challenging to find using standard screening techniques. Threats that are Changing: As science and technology evolve,

there is a chance that new, more powerful, and difficult-to detect explosives may be created, necessitating ongoing modification of detection and mitigation techniques. Regulatory Compliance: To prevent abuse, explosives are manufactured, sold, transported, and owned under tight regulations. For authorities, ensuring adherence to these standards is a difficult task. Unintentional Detonations: When handling, transporting, or storing explosives in industrial settings, unintentional detonations can happen, posing safety risks and raising environmental issues. Investigation complexity: Explosives forensic investigation includes intricate procedures and calls for specific knowledge and tools. Due to the presence of interfering compounds or post-blast fragmentation, the analysis might be difficult. Notice Time: Because certain high explosives react so quickly, there isn't much time for notice or action, which makes taking preventative steps difficult. Transportation Security: It is essential to secure the movement of explosives from producers to end users or disposal facilities in order to avoid theft, diversion, or terrorist acts while in transit. Border Explosives Detection: For border security organizations, it might be difficult to provide accurate explosives detection and screening at crossings and transit hubs. Due to their potential for having an adverse effect on the environment and the requirement for specific facilities and standards, explosives that have outlived their usefulness or have been seized create obstacles for safe disposal. Public Perception: Public worries regarding the use and management of explosives can result in social and political difficulties, affecting rules and guidelines for their usage. Regulatory authorities, security professionals, law enforcement organizations, and the general public must work together to address these issues. To address these issues and guarantee the responsible use of explosives, research and development in explosive detection technology, training programs for personnel handling explosives, and raised public knowledge of safety precautions are essential [12].

CASE STUDIES

Accidental Head Explosion

On New Year Eve, a case was reported where a 33 year old male victim was found with a ruptured head and died on the scene. In the report, it was stated that the victim was examined for a misfire of a hand made gun, and unfortunately, the cause of death was found to be the destruction of the head. This is the first documented case of a person losing his life due to explosives. The deceased had two major injuries on his body. One was considered the primary injury due to the interaction of pressure waves and the head. The second was considered the second injury due to a lot of bruising on his face, which is most likely due to black gun powder [19, 20].

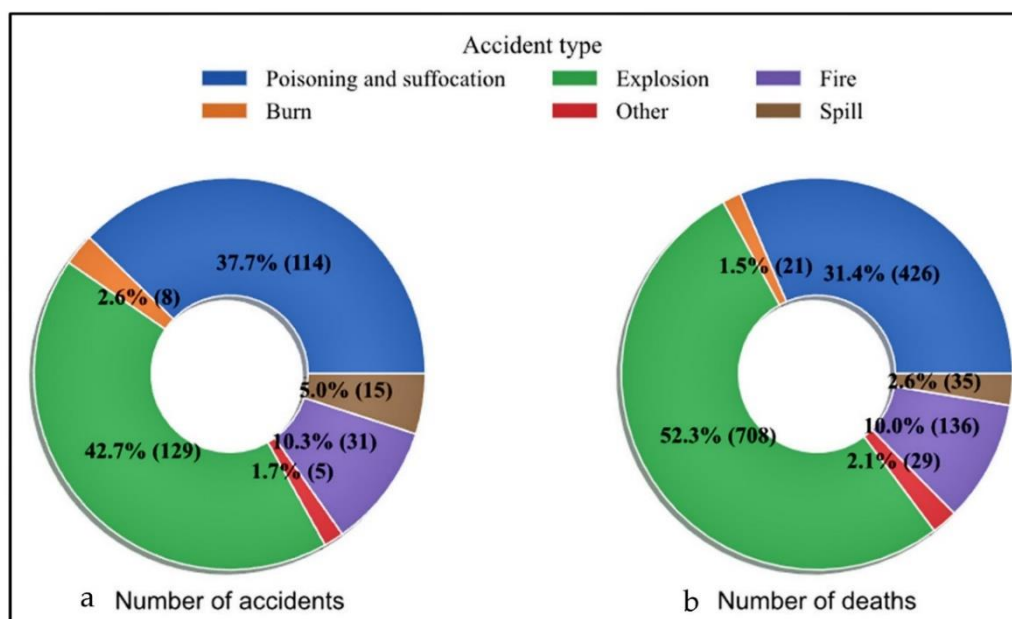


Fig. 1: Injuries and death due to explosives.

ROLE OF FORENSIC EXPERTS

In dealing with occurrences involving explosives and investigations, forensic specialists perform a critical and diverse role. It is impossible to comprehend, analyze, and interpret explosives-related data without their particular expertise and abilities. In explosives cases, forensic professionals play an important role in unraveling complicated criminal situations, presenting unbiased and scientifically reliable evidence, and upholding the rule of law. Their knowledge and experience contribute considerably to public safety and the effective conclusion of explosives-related criminal investigations [3, 21].

FUTURE DEVELOPMENTS IN EXPLOSIVES ANALYSIS

The discipline of explosives analysis is constantly developing, driven by technological improvements, scientific study, and the need to confront growing dangers. Here are some anticipated future breakthroughs in explosives analysis: Enhanced Detection Techniques: Increased sensitivity and quicker analysis times may result from advancements in current detection techniques like ion mobility spectrometry (IMS) and gas chromatography-mass spectrometry (GC-MS). These developments will make it possible to identify bombs more quickly and precisely in situations like security checks at airports or other public locations. Analytical equipment miniaturization will increase the accessibility and flexibility of explosives analysis. In order to help law enforcement and first responders fight terrorism and criminal activity, handheld gadgets that can detect and identify explosives on-site may become increasingly common. The development of very precise and sensitive detecting techniques is made possible by nanotechnology. Nanomaterials, such as nano-sensors and nano-probes, might improve the selectivity and sensitivity of explosives analysis, allowing for the

more precise identification of tiny levels of explosives. Machine Learning and Artificial Intelligence: Pattern recognition, data analysis, and explosive classification may all be made easier by incorporating machine learning techniques and artificial intelligence into the study of explosives. These technologies may aid in automating data interpretation, decreasing human error, and improving the effectiveness of forensic investigations. Novel Forensic Techniques: For example, improvements in DNA analysis and isotopic analysis might assist in identifying persons linked with explosives-related occurrences, and novel forensic techniques may arise to address obstacles in post-blast investigations and the examination of extensively polluted materials. Overall, the discipline of explosives analysis has a bright future because to continuing research and developments in technology. These advancements will improve our capacity to identify, assess, and respond to explosive threats, which will eventually lead to an increase in public safety and security [22].

CONCLUSION

The study of explosive trace evidence is a crucial part of forensic investigations and security operations, to sum up. Understanding the nature of explosive occurrences, connecting suspects to explosive devices, and identifying the source or origin of explosives used in criminal activities or acts of terrorism may all be done with the help of the identification and interpretation of minute traces of explosives. In order to analyze explosive trace evidence, a variety of sophisticated methods are used, such as colorimetric testing, ion mobility spectrometry, gas chromatography-mass spectrometry, Fourier transform infrared spectroscopy, X-ray diffraction, and more. Assuring adequate evidence collection, storage, and analysis, forensic professionals are

essential in managing explosive trace evidence. In court, their expert evidence enables the legal system to comprehend intricate scientific concepts and draw fair findings in situations involving explosives. Given the continuing dangers presented by explosives, it is essential to develop explosive trace evidence analysis in order to improve security protocols, safeguard public safety, and ensure the quick and efficient resolution of explosives-related occurrences. We can keep on top of the threat of explosives-related crime and terrorism and make the entire globe a safer place by ongoing study, technical advancements, and

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cooperation between specialists and government officials.

Author(s) Contribution: supervision, methodology and analysis, M. Afshan; resources, Noor UL Aien and K. Azka; review and editing, A. Minahil; proofreading, K. Azka.

Funding: No funding involved.

Ethical Approval: Not applicable

Conflict of Interest: Nil.

Consent for Publication: All authors approved the manuscript for publication.

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