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From ashes to evidence: Comprehensive review on the art of investigating arson

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Abstract

Arson, the intentional act of setting fire to property, poses a multifaceted challenge for forensic investigators. This detailed article explores the intricacies of identifying arson and understanding the diverse motives that underlie such acts. Incorporating a rich array of international, Indian, and terrorism-related case studies, we aim to provide an exhaustive analysis of the methods employed by forensic science investigators. This article highlights the protocols involved, advanced technologies used and some unique topics that are crucial for the deeper understanding of arson. The confluence of forensic odontology and arson has also been showcased by citing some case studies in this article. This article also seeks to contribute to the scholarly discourse on the evolving landscape of arson investigation.

Keywords: Arson; Fire investigation; Forensic odontology; Forensic science; Case studies; Disasters

1 Introduction

Arson, as a criminal act, demands specialized attention due to its intentional nature. The introduction sets the stage by elucidating the significance of understanding arson for forensic investigators. This article aspires to: a. Scrutinize the global panorama of arson cases. b. Uncover and analyse the diverse motives driving arson, ranging from personal motivations to acts of terrorism. c. Examine international and Indian case studies, incorporating terrorism-related incidents for a comprehensive understanding. d. Present a detailed overview of forensic science protocols to guide investigators in arson cases.

The term 'Arson' derives from Law French arsoun (late 13th century), from Old French arson. English Common Law defines arson as 'Arson is the act of willfully and deliberately setting fire to or charring property.'

Although the act of arson typically involves buildings, the term can also refer to the intentional burning of other things, such as motor vehicles, watercraft, or forests. The crime is typically classified as a felony, with instances involving risk to human life or property carrying a stricter penalty. Arson that results in death can be further prosecuted as manslaughter or murder.

A common motive for arson is to commit insurance fraud. In such cases, a person destroys their own property by burning it and then lies about the cause in order to collect against their insurance policy. The motives behind arson can be psychological, economic, and socio-political. Arson is also often committed to conceal another crime, such as murder or burglary.

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2 International Case Studies of Arson

2.1 Thomas Sweatt Arson (1985)

Thomas Sweatt set fire to a house, killing Bessie Mae Duncan and causing severe injuries to others, after following a stranger home.

2.2 H.L. Davis & Co. Clothing Store Arson (1995)

A fire at the H.L. Davis & Co. Clothing store in Rotan, Texas, resulted in the total loss of the store and two other commercial businesses, with damages estimated at over \$1 million.

2.3 The 2003 Rhode Island Nightclub Fire (2005)

A meticulous analysis of the Rhode Island nightclub fire, exploring the devastating consequences, investigative challenges, and lessons learned from this prominent international case [1].

2.4 Esperanza Fire (2006)

Raymond Lee Oyler was convicted of murder and sentenced to death for arson in a 2006 California wildfire that led to the deaths of five U.S. Forest Service firefighters.

2.5 The King's Cross Station Fire (2008)

A detailed examination of the King's Cross Station fire in London, shedding light on international variations in arson incidents and the corresponding investigative responses [2].

2.6 El Dorado Fire (2020)

A gender reveal party using a smoke bomb caused the El Dorado fire, resulting in one firefighter fatality and destruction of 20 structures.

2.7 Arson in the 9/11 attacks (2001)

The attacks on the World Trade Center on September 11, 2001, caused massive fires in the towers, which eventually led to their collapse.

3 Indian Case Studies of Arson:

3.1 Tuticorin Touring Cinema Fire (1979)

A fire in a touring cinema in Tuticorin, Tamil Nadu, during a matinee show, resulted in the deaths of 46 adults and 32 children.

3.2 Sabarmati Express Train Fire (2009, Godhra, India)

An in-depth analysis of the Sabarmati Express train fire, investigating the socio-political dimensions of arson in the Indian landscape and its implications for forensic investigations [3].

3.3 The AMRI Hospital Fire (2013, Kolkata, India)

A comprehensive exploration of the AMRI Hospital fire incident, addressing the unique challenges faced by forensic investigators in the Indian context, including legal and cultural considerations [4].

3.4 Saki Naka Snack Shop Fire (2017)

A fire at a snack shop in Saki Naka, Mumbai, caused by an electrical short circuit and gas cylinder explosion, resulted in 12 deaths.

4 Case Studies Highlighting Arson and Terrorism

4.1 The 2004 Madrid Train Bombings (Spain)

Investigating the interconnectedness of terrorism and arson through a detailed examination of the Madrid Train bombings, emphasizes the forensic challenges encountered in such complex cases [5].

4.2 The 2008 Mumbai Attacks (India)

A nuanced exploration of the use of arson as a tactic in the 2008 Mumbai attacks, focusing on the forensic intricacies faced by investigators in the aftermath of this devastating incident [6].

5 Forensic Investigation Protocols

5.1 Initial Response

It involves the pivotal role of first responders in securing the scene, preserving evidence, and facilitating a seamless transition to the investigative phase [7].

5.2 Evidence Collection

Following the evidence collection protocols is highly crucial, encompassing the identification and analysis of accelerants, fire debris, and other critical forensic elements [8].

5.3 Laboratory Techniques

A thorough examination using the advanced laboratory techniques in arson investigations, includes DNA analysis, forensic profiling, and cutting-edge analytical methods [9].

6 Fiber-Burn Interaction

Every fiber reacts differently when comes in contact with fire. The nature of flame, smell and properties of residue can significantly help in understanding the quality of the material burnt in arson. Some of the commonly found fibers and their properties after getting burnt are shown in the table below (Table 1).

Table 1 Fire-fiber interaction properties of certain fibers

Fiber	Reaction to Flame	Odour	Residue
Cotton	Burns with orange-yellow flame	Burning Paper	Gray ash
Wool	Burns with sizzling flame, self-extinguishing in nature	Burning hair	Crisp, irregular, crushable black bead
Silk	Ignites sparkling flame, self-extinguishing in nature	Burning hair (less pungent than wool)	Crisp, round, crushable black bead
Acrylic	Melts as it burns, bright sputtering flame, black smoke	Acid-like	Hard, irregular black bead
Polyester	Fuses and shrinks from flame, burns slowly, melting, self-extinguishing	Heavy pungent	Hard, brownish beige bead

7 Advanced Technologies used in Arson Investigations

7.1 EDXRF (Energy Dispersive X-Ray Fluorescence)

The fire debris can be non-destructively analysed using EDXRF. Trace elements can be quickly and precisely analyzed using EDXRF.

7.2 Mass Spectrometry (GC-MS)

Mass spectrometry, particularly gas chromatography-mass spectrometry (GC-MS), is a highly important tool in arson investigations that helps in the identification and analysis of ignitable liquid residues (accelerants) at fire scenes. Accelerants provide hints for how the fire was started or spread.

7.2.1 GC-MS Analysis

Gas Chromatography (GC): Separates the volatile components of the fire debris sample.

Mass Spectrometry (MS): Identifies the separated components by their mass-to-charge ratio, providing a unique "fingerprint" of the accelerant.

7.2.2 Comparison Microscope

In order to analyse a piece of evidence that is found to be partially destroyed, comparison microscope helps in 1:1 comparison of the destroyed and undestroyed pieces of that evidence together at a time. This tool ultimately helps in the detailed examination of evidences, giving hints of the nature and pattern of arson along with fine properties of the materials involved.

7.2.3 Virtual Reality/Augmented Reality Tools

How it works: VR/AR technology allows investigators to virtually reconstruct and explore the fire scene, enhancing their understanding of the fire's origin and spread.

7.3 Benefits

- Improves the formulation of hypotheses about the fire's cause and origin.
- Enhances confidence in the investigation's findings.
- Provides a more immersive and detailed understanding of the fire scene.

7.4 Other Emerging Technologies

- Drones: Equipped with thermal imaging cameras, drones can provide firefighters with real-time insights into a fire's location and spread.
- Thermal Imaging Cameras: Help identify hot spots and areas of heat concentration.
- Fire Behaviour Modelling Software: Allows investigators to simulate fire behaviour and predict how fires will spread in different scenarios.
- Digital Imaging and Mapping Technologies: Enhance analysis capabilities, allowing investigators to examine fire scenes with a higher level of detail.
- Photoionization Detector (PID) technology: This technology can support fire/arson investigations.

8 Security protocols

Security protocols for forensic investigators in arson cases are crucial to ensure the safety of the investigators, the integrity of the evidence, and the success of the investigation. The following security protocols provide a comprehensive framework for forensic investigators dealing with arson cases:

8.1 Scene Safety Assessment

- Prioritize Safety: Before entering the scene, investigators must assess potential hazards and prioritize their safety. This includes identifying structural instability, hazardous materials, and potential dangers like gas leaks.
- Coordination with First Responders: Collaborate with first responders to obtain information about any immediate dangers or ongoing firefighting activities. Ensure a seamless transition from the first response phase to the forensic investigation.

8.2 Personal Protection

- Personal Protective Equipment (PPE): Mandatory Gear: Investigators should wear appropriate PPE, including flame-resistant clothing, helmets, gloves, and eye protection, to safeguard against potential hazards such as residual fire, chemical substances, or sharp objects.

- **Respiratory Protection:** In situations where toxic fumes or chemicals may be present, investigators must use respiratory protective equipment to prevent inhalation hazards.

8.3 Access Control

- **Limited Access:** Restrict access to the crime scene to authorized personnel only. Control entry points to prevent contamination and preserve the integrity of evidence.
- **Identification and Logging:** Maintain a log of all individuals entering and exiting the crime scene, recording their identities, roles, and timestamps. This log helps establish a chain of custody.

8.4 Communication Protocols

- **Secure Channels:** Use secure and encrypted communication channels for discussing case details, sharing findings, and coordinating with team members to prevent unauthorized access or interception.
- **Team Coordination:** Establish clear communication protocols among team members, ensuring efficient collaboration without compromising sensitive information.

8.5 Equipment Security

- **Secure Storage:** Safeguard forensic tools and equipment in a secure, controlled environment when not in use to prevent theft or tampering.
- **Chain of Custody:** Document the handling and transfer of all forensic evidence, maintaining a meticulous chain of custody to ensure its admissibility in court.

8.6 Digital Security

- **Data Encryption:** Encrypt all digital data, including reports, photographs, and analysis results, to protect sensitive information from unauthorized access.
- **Cybersecurity Measures:** Implement cybersecurity measures to safeguard digital forensic tools and databases against hacking or data breaches.

8.7 Personnel Screening:

- **Background Checks:** Conduct thorough background checks on all forensic investigators to ensure their reliability and trustworthiness.
- **Confidentiality Agreements:** Require investigators to sign confidentiality agreements, emphasizing the importance of nondisclosure regarding case details.

9 Post-Investigation Security

- **Secure Evidence Storage:** Ensure that all collected evidence is securely stored in designated, controlled environments to prevent contamination or loss.
- **Disposal Protocols:** Implement secure protocols for the disposal of hazardous materials, ensuring compliance with environmental regulations.
- **Training and Awareness with Regular Training:** Provide ongoing training for forensic investigators on the latest security protocols, technological advancements, and safety measures.
- **Crisis Response Training:** Equip investigators with crisis response training to handle unexpected situations and emergencies effectively.
- **Legal and Ethical Compliance: Adherence to Regulations:** Ensure investigators adhere to local, national, and international regulations governing forensic investigations.

9.1 Ethical Standards

Uphold high ethical standards, emphasizing the importance of impartiality, integrity, and professionalism in all aspects of the investigation.

Implementing these security protocols ensures that forensic investigators can carry out their work effectively while mitigating risks and maintaining the integrity of the investigative process. Regular reviews and updates to these protocols are essential to adapt to evolving forensic science practices and security threats.

9.2 Documentation of Evidence

Documentation is a critical aspect of arson investigation, ensuring that investigators capture, record, and preserve information and evidence accurately. The documentation process aids in reconstructing the scene, supporting findings, and presenting evidence in legal proceedings. Here are key documentation techniques in arson investigation:

- **Photography:** a. Overview Shots: Capture overall scenes to provide context and document the layout of the area affected by the fire. b. Close-Up Shots: Take detailed photographs of specific points of interest, such as ignition points, burn patterns, and evidence items. c. Progression Photos: Document the stages of the investigation, from the initial scene assessment to evidence collection and scene processing. d. Photograph Scales: Include measurement scales or markers in photographs to provide a sense of size and distance.
- **Videography:** a. 360-Degree Videos: Record panoramic videos of the scene to provide a comprehensive view for later analysis. b. Narration: Provide verbal narration while recording videos to explain observations, procedures, and significant findings.
- **Sketches and Diagrams:** a. Rough Sketches: Create initial rough sketches of the scene, indicating the locations of major items, entry and exit points, and fire patterns. b. Detailed Diagrams: Develop more detailed and accurate diagrams as the investigation progresses, incorporating measurements and annotations.
- **Field Notes:** a. Detailed Descriptions: Record detailed descriptions of the scene, noting the conditions, weather, and any unusual observations. b. Observations and Findings: Document the investigator's observations, findings, and preliminary conclusions during the on-site examination. c. Witness Statements: Include summaries of statements from witnesses, firefighters, and other relevant personnel.
- **Chain of Custody:** a. Documentation Forms: Use standardized chain of custody forms for each piece of evidence, including details such as item description, date and time of collection, and names of individuals handling the evidence. b. Sealing Procedures: Document the process of sealing evidence containers, including the type of seal used and the signatures of those involved.
- **Evidence Tags and Labels:** a. Uniform Labelling: Use consistent labelling for all evidence items, indicating the case number, item number, and a brief description. b. Material Descriptions: Include material descriptions, colour, size, and any distinctive features on evidence tags.
- **Measurements:** a. Photographic Scaling: Use objects of known dimensions (e.g., rulers, scales) in photographs to establish a scale for measurements. b. Instrument Measurements: Utilize measurement tools, such as tape measures and rulers, to document the dimensions of burn patterns and other relevant features.
- **Documentation Software:** a. Digital Platforms: Employ digital documentation tools and software to organize and store information efficiently. b. GIS (Geographic Information System): Use GIS for mapping and spatial analysis, especially when investigating large or complex scenes.
- **Recordings of Interviews:** a. Audio Recordings: Record interviews with witnesses, suspects, or relevant personnel to maintain an accurate account of statements. b. Transcriptions: Create transcriptions of recorded interviews for inclusion in case files.
- **Weather Data:** Meteorological Data: Document weather conditions, including temperature, wind speed, and humidity, as they can impact fire behaviour.
- **Laboratory Analysis Documentation:** Laboratory Reports: Maintain detailed records of all laboratory analyses performed on collected evidence.
- **Findings and Interpretations:** Document the conclusions drawn from laboratory analyses, including the significance of each result.

9.2.1 Timeline Construction

Chronological Record- Develop a chronological timeline of events, from the initial incident to the conclusion of the investigation, incorporating all significant actions and findings.

By employing these documentation techniques, forensic investigators enhance the accuracy, reliability, and completeness of their investigative records in arson cases. Thorough documentation is essential for building a strong case, ensuring transparency, and providing a basis for expert testimony in legal proceedings.

10 Case Scenarios Involving the Confluence of Arson and Forensic Odontology

- **The "Charred Remains" Case:** Forensic odontology has been used to solve cases where victims were found as charred remains, like the case of Mary Lynn Breeden, where tooth pulp was used to convict a suspect.
- **Mass Disasters:** Forensic odontologists play a crucial role in identifying victims in mass disasters, such as fires, explosions, or natural disasters, where numerous bodies are involved.

- Studio Arson Attack in Japan: A studio arson attack in Japan caused 36 deaths, and dentists obtained dental findings from 33 unidentified bodies to aid in identification.
- Winfield Scott Goss Case: In 1873, a fire at a cottage workshop in Maryland resulted in a charred body, and forensic odontology helped determine if the body was indeed Winfield Scott Goss.

11 Key Findings of the Article

The synthesis of findings from diverse case studies underscores the nuanced patterns and distinct characteristics associated with arson across different contexts. The Rhode Island nightclub fire exemplifies the catastrophic consequences of arson in a crowded setting, emphasizing the imperative for meticulous investigations [1]. The King's Cross Station fire in the UK showcases the importance of recognizing international variations in arson incidents, necessitating tailored investigative responses [2]. The analysis of Indian case studies, such as the AMRI Hospital fire and the Sabarmati Express train fire, unveils the unique challenges faced by forensic investigators in the Indian landscape, ranging from cultural considerations to socio-political dimensions [3,4].

12 Implications of Arson

The implications of arson extend beyond the realm of forensic science, permeating into law enforcement, public policy, and societal awareness. Arson, when linked to terrorism, as seen in the Madrid Train bombings and the 2008 Mumbai attacks, amplifies the need for collaborative international efforts in investigation and prevention [5,6]. The careful examination of forensic investigation protocols, encompassing initial response, evidence collection, laboratory techniques, and expert testimony, highlights the critical role of forensic science in ensuring a thorough and credible investigative process.

13 Conclusion

The comprehensive exploration of arson and its myriad facets, including identification, motives, and investigative protocols, sheds light on the intricate nature of this intentional act of destruction. Through an in-depth analysis of international, Indian, and terrorism-related case studies, coupled with an examination of forensic science protocols, this article has contributed to our understanding of the challenges faced by investigators in investigating the complexities of arson. The importance of forensic odontology in arson has also been highlighted through some case studies in the article.

As we navigate the complex landscape of arson, future research should focus on advancements in forensic technologies, collaboration between international investigative agencies, and the development of standardized protocols to address the nuances of arson investigations. Additionally, fostering interdisciplinary collaboration between forensic scientists, psychologists, and sociologists can enhance our understanding of the motives behind arson, leading to more effective prevention strategies.

In conclusion, this comprehensive exploration of arson and its motives contributes to the ever-evolving field of forensic science. By delving into the intricacies of intentional fire-setting, we move closer to a holistic understanding that can inform both investigative practices and preventative measures, ultimately fostering a safer and more secure society.

Compliance with ethical standards

Disclosure of conflict of interest

The authors hereby declare that no conflicts of interest exist.

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