

“DNA PROFILING AND CRIME SCENE MANAGEMENT: A SCIENTIFIC APPROACH TO CRIMINAL INVESTIGATION”

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ABSTRACT

The delivery of criminal justice increasingly relies on scientific investigative techniques in order to guarantee accuracy, reliability and fairness in the detection and prosecution of crimes. Among the range of forensic techniques available today, DNA profiling has become one of the most important tools for the identification of individuals and the establishment of links between suspects, victims and crime scenes. However, the effectiveness of DNA evidence is heavily dependent on proper crime scene management, as any error in the collection, preservation or handling of biological evidence may jeopardize the reliability of forensic results. This paper investigates the synergistic relationship between DNA profiling and crime scene management as components of modern criminal investigation. This paper discusses the concept of corpus delicti, basic principles of forensic science and the importance of systematic analysis of the crime scene in order to maintain the evidentiary value. The paper also discusses the historical development, the scientific basis, sources and processes of DNA profiling with emphasis on the identification of the offenders, victims and exoneration of innocent persons. Special attention is paid to processes of handling and preserving biological evidence and the importance of maintaining the chain of custody. The paper also discusses significant judicial pronouncements which have recognized the evidentiary value of DNA profiling and addresses the practical and legal issues regarding crime scene management and forensic DNA analysis. It is found that efficient management of crime scenes and precise DNA profiling are indispensable for improved criminal investigations and to boost the credibility of the criminal justice system. The study suggests improved forensic infrastructure, specialised training, standard protocols and robust legal safeguards to exploit the potential of DNA based evidence in criminal proceedings.

KEY WORDS: Corpus Delicti, DNA Profiling, Forensic Science, Crime Scene Management, Criminal Justice System

INTRODUCTION

Science and technology have completely changed the dimension of studying crime. The old methods of investigation were dependent on the evidence of eyewitnesses, confessions and circumstantial evidence which often made it difficult to identify the criminals correctly and establish the facts of a case.¹⁵²⁸ The introduction of scientific methods has changed the face of

criminal investigations with the use of forensic science, which gives objective and reliable evidence. Today, forensic science plays an integral role in unraveling the truth, identifying the culprits and bringing to justice those who have committed a crime with factual and scientific evidence. Forensic science applies scientific methods to criminal and civil laws enforced by police agencies in a criminal justice

¹⁵²⁸ Saferstein, Richard, “The Evolution of Forensic Science and Criminal Investigation”, 55(3) *Journal of Forensic Sciences* 589 (2010).

system.¹⁵²⁹ It includes a variety of fields such as fingerprint analysis, toxicology, ballistics, digital forensics and DNA profiling. DNA profiling is one of the most potent and reliable means of individual identification among these fields due to the unique genetic characteristics of each individual (except identical twins).¹⁵³⁰ This method enables investigators to establish connections between suspects, victims and crime scenes by examining biological samples like blood, saliva, hair, semen, skin cells, bones and teeth with high precision. However, a proper management of a crime scene is necessary for the effective use of DNA evidence. A crime scene is the primary source of physical and biological evidence that can help investigators to reconstruct events and to identify criminals. If a crime scene is not properly managed, critical evidence can be contaminated, degraded or lost, which can compromise the integrity of forensic analyses. A systematic approach is therefore necessary to the securing, documenting, searching, collection, preservation and transportation of evidence in accordance with established forensic protocols.¹⁵³¹

It is therefore of utmost importance to associate DNA profiling with crime scene management. DNA profiling offers scientific certainty of individual identification while crime scene management allows for the proper collection and preservation of biological evidence that is required for such analysis. The reliability and admissibility of DNA evidence in legal contexts depend not only on laboratory analysis but also on how the evidence is managed from the time it is found at the crime scene. The important factors that affect the evidentiary value of DNA samples are preservation of chain of custody, standardized procedures and prevention of contamination.¹⁵³² DNA profiling has played a key role in solving complex criminal cases, disaster

victim identification, missing persons and exonerating wrongfully convicted individuals, in recent years. DNA evidence has increasingly been accepted by courts around the world as a very reliable type of scientific evidence.¹⁵³³ Nevertheless, challenges such as lack of forensic infrastructure, lack of trained manpower, privacy concerns and delays in laboratory analysis continue to hinder its effective use. In the present light, the present study seeks to explore the scientific and practical dimensions of DNA profiling and crime scene management in criminal investigations. It discusses the principles of forensic science, methodologies of crime scene investigation, scientific basis of DNA profiling and procedures for collection and preservation of biological evidence, and reviews relevant case laws, challenges and recommendations to strengthen the role of forensic science in the administration of criminal justice.¹⁵³⁴

PRINCIPLES OF FORENSIC SCIENCE

Corpus delicti is a Latin term meaning literally “body of the crime.” In criminal law, it is the proof necessary to show that a crime has been committed. Although the literal translation would seem to imply a dead body, corpus delicti is based on the fact that a particular crime has been committed, and that the crime resulted from a criminal act. One of the main goals of any criminal investigation is corpus delicti because, without proof that a crime has been committed, there is no way to convict anyone on the basis of suspicion or confession alone. The idea of corpus delicti is an important safeguard against wrongful convictions and an essential element of a fair system of criminal justice.¹⁵³⁵ Before investigators can begin to search for who committed the crime, they first must establish enough evidence that a crime was actually

¹⁵²⁹ T. V. Aswathy & V. Balamurugan, “Role of Forensic Science in Criminal Justice Delivery System”, 8(2) *Indian Journal of Forensic Medicine & Toxicology* 112 (2014).

¹⁵³⁰ S. K. Sharma, “Modern Trends in Forensic Science”, 9(4) *Indian Journal of Criminology and Criminalistics* 55 (1981).

¹⁵³¹ National Institute of Justice, *Crime Scene Investigation: A Guide for Law Enforcement* (U.S. Department of Justice, 2013).

¹⁵³² Peter Gill, “DNA Evidence and the Importance of Evidence Integrity”, 58(1) *Forensic Science International: Genetics* 1 (2014).

¹⁵³³ David H. Kaye, “The Double Helix and the Law of Evidence”, 23(2) *Harvard Journal of Law and Technology* 271 (2010).

¹⁵³⁴ B. B. Nanda & R. K. Tiwari, “Challenges in the Application of DNA Technology in India”, 35(1) *Journal of Forensic Research and Criminal Investigation* 22 (2019).

¹⁵³⁵ B. R. Sharma, “Forensic Science and the Administration of Criminal Justice”, 24(3) *Journal of Indian Academy of Forensic Medicine* 97 (2002).

committed. In a homicide case, for example, the first task is to ascertain that a person actually died and that the death was the result of illegal activity. Scientific evidence found at the crime scene often forms the basis of the proof of these essential facts.¹⁵³⁶

Forensic science is critical to the proof of the corpus delicti, since it entails the analysis of physical and biological evidence. Investigators use bloodstains, fingerprints, weapons, hair samples, DNA evidence and other forms of evidence to piece together what happened and if a crime was committed.¹⁵³⁷ In modern criminal investigation scientific evidence is usually more reliable than testimonial evidence as it is based on objective analysis rather than on human memory or perception. There are a number of key principles that guide the use of forensic science.

Principle of Individuality

One of the most important is the Principle of Individuality. This states that every object, person or event has different characteristics which sets it apart from others. DNA profiling is a prime example of this principle as every individual has a unique genetic profile which can be used for identification.¹⁵³⁸

Principle of Exchange

Another significant principle is Locard's Exchange Principle, developed by the French criminologist Edmond Locard. The Transfer Principle is based on the fact that when two objects come into contact, there is a reciprocal transfer of material. As a result, in a criminal investigation, the perpetrator of a crime inevitably leaves traces of himself or herself at the scene of the crime and also takes traces away from the scene of the crime. DNA evidence such as blood, saliva, skin cells, or hair can be recovered thanks to this principle and can be

used to establish important links between a suspect and a criminal act.¹⁵³⁹

Principle of Comparison

The Principle of Comparison states that the identification of evidence requires a comparison with known standards. Thus, DNA samples from a crime scene are compared with reference samples taken from suspects, victims or databases to determine whether there is a match.¹⁵⁴⁰

Principle of Probability

The Principle of Probability recognizes that forensic conclusions are often expressed in terms of statistical likelihood rather than absolute certainty. DNA profiling involves the use of probability calculations to establish the likelihood that a DNA profile could be that of a particular individual. The very low probability that two unrelated people would have the same DNA profile increases the reliability of DNA evidence.¹⁵⁴¹

Principle of Reconstruction

The Principle of Reconstruction enables the investigators to reconstruct the sequence of the events of a crime from the evidence available to them. Forensic investigators use the principles of physical evidence, biological materials and environmental factors to build a scientific view of the commission of an offence. Together, these principles form the basis of forensic science and guide the investigation of crimes. They emphasize the role of scientific evidence in establishing the corpus delicti. They demonstrate the importance of DNA profiling in the investigation of the crimes of today.¹⁵⁴²

CRIME SCENE MANAGEMENT AND CRIME SCENE EXAMINATION

A crime scene is a location where a crime has been committed or where evidence relating to a

¹⁵³⁶ Hanumant Govind Nargundkar v. State of Madhya Pradesh, AIR 1952 SC 343.

¹⁵³⁷ R. Saferstein, "The Role of Physical Evidence in Establishing Corpus Delicti", 47(2) *Journal of Forensic Sciences* 215 (2002).

¹⁵³⁸ A. J. Jeffreys, V. Wilson & S. L. Thein, "Individual-specific Fingerprints of Human DNA", 316 *Nature* 76 (1985).

¹⁵³⁹ Edmond Locard, "The Analysis of Dust Traces", 1(4) *American Journal of Police Science* 276 (1930).

¹⁵⁴⁰ John M. Butler, "Forensic DNA Typing and Human Identification", 44(5) *BioTechniques* 38 (2008).

¹⁵⁴¹ Ian W. Evett, "Interpretation of DNA Evidence and Probability Theory", 37(1) *Journal of Forensic Sciences* 25 (1992).

¹⁵⁴² P. K. Dash, "Crime Scene Reconstruction and Scientific Investigation", 33(2) *Indian Journal of Criminology* 45 (2005).

crime can be found. It is the primary source of physical and biological evidence that helps investigators to understand the circumstances in which a crime has occurred. Examination of the crime scene is one of the most important stages in a criminal investigation because the quality of the evidence collected at this stage greatly influences the quality of the subsequent forensic and legal proceedings. Failure to properly manage the crime scene may result in the loss, contamination or destruction of important evidence and thus hinder the pursuit of justice.¹⁵⁴³

Examination of a crime scene is the systematic way of identifying, documenting, collecting, and safeguarding evidence present at the scene of a crime. The main objective is to uncover facts that can confirm the commission of a crime, determine the offender, reconstruct the sequence of events and provide reliable evidence for judicial proceedings. Investigations must be scientifically designed, carefully structured and meet forensic standards, so that the integrity of the evidence is maintained and it remains admissible.¹⁵⁴⁴

A primary objective of a crime scene investigation is to establish the corpus delicti of the crime. Law enforcement officers must establish whether a crime has been committed and, if so, gather evidence that can establish the commission of the crime. Physical and biological evidence recovered from the scene often provides vital information as to the nature of the crime, the methods used by the offender, and the identities of those involved.¹⁵⁴⁵ In addition, examination of the crime scene helps to identify suspects through the analysis of fingerprints, footprints, bloodstains, hair samples, traces of DNA, weapons and other incriminating items that may link an individual to the crime.

Investigating a crime scene requires a range of scientific methods to guarantee that every piece

of evidence is gathered and recorded. The first step in a review is an initial survey of the scene. During this survey, investigators evaluate the totality of the scene, identify potential evidence and develop a plan for a comprehensive examination. This initial assessment allows investigators to determine the resources and expertise necessary to investigate the scene.

One of the most important aspects of crime scene analysis is documentation. The condition of evidence must be carefully documented before it is disturbed or removed. Photography is a common means of recording the condition of the crime scene, as well as the location of evidence. Such photographs provide a permanent visual record for investigative and judicial purposes. Videography augments photography by documenting the general layout of the scene and the relative location of various pieces of evidence. Investigators also create crime scene sketches that include specific measurements of the scene and the location of evidence. Detailed written notes record observations not seen in photographs or sketches.¹⁵⁴⁶

Techniques of the Crime Scene Management

In addition to documenting, investigators use a variety of techniques to systematically search crime scenes to locate evidence. The spiral search method is effective in open areas and involves moving inward or outward in a spiral pattern. The grid search method involves investigators conducting two different searches at right angles to each other, increasing the likelihood of finding evidence. The strip or line search method involves searching parallel strips of an area and is often used in large crime scenes. The zone search method involves dividing the crime scene into smaller areas and searching each area separately.¹⁵⁴⁷ The type of

¹⁵⁴³ Susan Ballou, "Crime Scene Evidence: The Importance of Proper Recognition, Collection and Preservation", 31(2) *Forensic Science Communications* 14 (2002).

¹⁵⁴⁴ S. H. James & J. J. Nordby, *Forensic Science: An Introduction to Scientific and Investigative Techniques* 103 (4th edn., CRC Press, 2015).

¹⁵⁴⁵ Max M. Houck & Jay A. Siegel, *Fundamentals of Forensic Science* 103 (3rd edn., Academic Press, 2015).

¹⁵⁴⁶ Ross M. Gardner, *Practical Crime Scene Processing and Investigation* 145 (2nd edn., CRC Press, 2012).

¹⁵⁴⁷ Richard Saferstein, *Criminalistics: An Introduction to Forensic Science* 72 (11th edn., Pearson Education, 2015).

search method used depends on the nature, size and location of the crime scene.

Crime scene management is more than an examination; it is the process of control, protection, documentation, collection, preservation, and transportation of evidence.¹⁵⁴⁸ Effective crime scene management begins when you secure the scene when you first arrive. No unauthorized persons should be allowed into the area so as not to contaminate or disturb any evidence. The scene must be kept intact to preserve the validity of any future forensic investigation. A secure perimeter must be established.

Once the scene is safe the investigators record and collect evidence. Each piece of evidence is identified, tagged, packaged and logged. Biological evidence such as blood, saliva, semen, hair and skin cells must be handled with special care as it may be used for DNA profiling at some later time.¹⁵⁴⁹ Mishandling biological evidence can result in contamination or degradation and DNA analysis will not be possible.

Ensuring the chain of custody is an integral part of crime scene management. Chain of custody is the written record of collection, handling, transfer, storage and examination of evidence from the time of its discovery to the time of its presentation in court.¹⁵⁵⁰ The ability of crime scene management to maintain the evidentiary integrity of both physical and biological materials is significant. Scientific methods such as DNA profiling rely on the availability of uncontaminated and sufficiently preserved samples.

Therefore, effective crime scene management is the foundation stone of contemporary forensic investigation. It links the process of identifying evidence with scientific evaluation, thus ensuring that justice is done based on reliable and

credible information. The investigation and management of the crime scene are therefore critical components of criminal investigations. Through systematic documentation, scientific search techniques, thorough collection of evidence and strict compliance with forensic protocols investigators can conserve the critical evidence and allow for correct forensic analysis.¹⁵⁵¹ The importance of the practice is particularly clear in the case of DNA profiling where the reliability of forensic results depends on the quality of biological evidence collected at the crime scene.

DNA PROFILING: MEANING AND HISTORICAL DEVELOPMENT

DNA (*Deoxyribonucleic Acid*) serves as the hereditary material found in the cells of nearly all living organisms.¹⁵⁵² It holds genetic information that defines an individual's biological traits and is transmitted from one generation to the next.¹⁵⁵³ Each person has a distinct DNA pattern, with the exception of identical twins, which renders DNA an invaluable resource for personal identification. In the realm of forensic science, DNA profiling is the scientific method employed to identify individuals by examining specific segments of their DNA and comparing these with biological samples obtained from a crime scene.

The origins of DNA profiling can be traced back to the discovery of the double-helix structure of DNA by James Watson and Francis Crick in 1953. This pivotal discovery established the groundwork for contemporary genetic science and allowed researchers to comprehend how genetic information is stored and inherited. Further advancements in molecular biology uncovered that certain segments of human DNA differ among individuals, enabling the differentiation of one person from another through genetic analysis.¹⁵⁵⁴

¹⁵⁴⁸ Barry A.J. Fisher & David R. Fisher, *Techniques of Crime Scene Investigation* 101 (8th edn., CRC Press, 2012).

¹⁵⁴⁹ Peter Gill, "DNA Evidence and the Importance of Evidence Integrity", 58(1) *Forensic Science International: Genetics* 1 (2014).

¹⁵⁵⁰ S. Walsh, "Forensic DNA Evidence and Chain of Custody Requirements", 17(3) *International Journal of Evidence and Proof* 201 (2013).

¹⁵⁵¹ Robin Williams & Paul Johnson, "DNA Profiling and Contemporary Criminal Investigation", 46(1) *British Journal of Criminology* 1 (2006).

¹⁵⁵² John M. Butler, *Fundamentals of Forensic DNA Typing* 3 (Academic Press, 2010).

¹⁵⁵³ Bruce Alberts et al., *Molecular Biology of the Cell* 455 (6th edn., Garland Science, 2014).

¹⁵⁵⁴ David J. Balding & Peter Donnelly, "The Probability of Matching DNA Profiles", 31(4) *Science and Justice* 221 (1991).

A significant advancement occurred in 1984 when Alec Jeffreys, a British geneticist, pioneered the technique of DNA fingerprinting at the University of Leicester. The first notable criminal application of this technique emerged during the investigation of the Narborough Murders in England. Two young girls had been murdered, and although a suspect had confessed, DNA testing revealed that he was not the perpetrator. Additional DNA screening ultimately led investigators to the true offender, Colin Pitchfork, marking it as the first criminal case globally to be resolved through DNA profiling. This landmark case illustrated the capacity of DNA evidence not only to identify criminals but also to clear innocent individuals, solidifying DNA profiling as one of the most dependable forensic tools in contemporary criminal investigations.¹⁵⁵⁵

ROLE OF CRIME SCENE MANAGEMENT IN DNA PROFILING

Crime scene management and DNA profiling are intricately linked elements of contemporary criminal investigations. DNA profiling offers a scientific approach to identifying individuals based on their genetic traits; however, the effectiveness of DNA analysis is heavily reliant on how biological evidence is located, collected, preserved, and transported from the crime scene. Even the most sophisticated DNA technology cannot yield dependable results if the evidence has been tainted, deteriorated, or mishandled during the initial investigative phases. Thus, efficient crime scene management is fundamental to the accuracy of DNA profiling.¹⁵⁵⁶

The main goal of crime scene management is to maintain the integrity of evidence. Common sources of DNA evidence include biological materials such as blood, saliva, semen, hair, skin cells, bones, and teeth. These materials are often delicate and highly vulnerable to contamination from environmental influences, investigators,

medical staff, or the public.¹⁵⁵⁷ Therefore, it is imperative for investigators to secure the crime scene promptly and limit unauthorized access to avert interference with potential DNA evidence. Utilizing protective gear such as gloves, masks, and evidence collection kits significantly mitigates the risk of contamination.¹⁵⁵⁸

The correct collection and preservation of biological evidence are crucial for effective DNA profiling. Investigators must pinpoint potential DNA sources and gather them following scientifically validated protocols. Each piece of evidence should be meticulously packaged, labeled, and documented to guarantee that its origin and condition can be verified throughout the investigation. Wet biological samples must be dried prior to packaging, and different items should be stored separately to avoid cross-contamination. Neglecting to adhere to these protocols may jeopardize the quality of DNA samples and diminish their evidentiary significance.

Crime scene management is essential for maintaining the chain of custody, which is the documented history of every person who has handled evidence from its collection to its presentation in court. A continuous chain of custody guarantees the authenticity and reliability of DNA evidence. Any gaps in this process may lead the defense to question the credibility and admissibility of the evidence, thereby undermining the prosecution's case. Therefore, meticulous documentation and accountability are vital components of crime scene management.

The importance of crime scene management is also acknowledged in Indian law. Section 176 of the Bharatiya Nagarik Suraksha Sanhita, 2023 requires forensic investigation for offenses punishable by imprisonment of seven years or more.¹⁵⁵⁹ This provision underscores the legislative focus on scientific investigative

¹⁵⁵⁵ Erin Murphy, "The New Forensics: Criminal Justice, False Certainty and the Second Generation of Scientific Evidence", 95(3) *California Law Review* 721 (2007).

¹⁵⁵⁶ Barry A.J. Fisher & David R. Fisher, *Techniques of Crime Scene Investigation* 101 (8th edn., CRC Press, 2012).

¹⁵⁵⁷ Susan Ballou, "Crime Scene Evidence: The Importance of Proper Recognition, Collection and Preservation", 31(2) *Forensic Science Communications* 14 (2002).

¹⁵⁵⁸ National Institute of Justice, *Crime Scene Investigation: A Guide for Law Enforcement* 9 (U.S. Department of Justice, 2013).

¹⁵⁵⁹ Bharatiya Nagarik Suraksha Sanhita, 2023, s. 176.

methods and emphasizes the increasing significance of preserving forensic evidence from the initial stages of criminal proceedings. Effective crime scene management guarantees that biological evidence suitable for DNA analysis is secured and examined in compliance with legal standards.¹⁵⁶⁰

Consequently, the relationship between crime scene management and DNA profiling can be characterized as one of interdependence. Crime scene management aids in the recovery and preservation of DNA evidence, while DNA profiling converts that evidence into scientifically reliable information that can identify offenders, connect suspects to crime scenes, identify victims, and eliminate innocent individuals from suspicion. Together, they enhance the accuracy, objectivity, and credibility of criminal investigations and play a crucial role in the administration of justice.

IMPORTANCE OF DNA PROFILING

DNA profiling has emerged as one of the most vital instruments in contemporary criminal investigations, owing to its exceptional accuracy and dependability. Given that each person has a distinct genetic profile, DNA analysis allows investigators to accurately identify suspects and establish connections between individuals and crime scenes with significant precision. It offers scientific evidence that is frequently more trustworthy than eyewitness accounts or circumstantial evidence. DNA profiling is essential in the investigation of serious crimes such as murder, rape, kidnapping, and terrorism-related offenses. It aids in identifying perpetrators, associating suspects with criminal activities, and eliminating innocent individuals from suspicion. Furthermore, DNA profiling is extensively utilized for victim identification in scenarios involving mass disasters, missing persons, and unidentified human remains.¹⁵⁶¹

Another notable benefit of DNA profiling is its capacity to avert wrongful convictions by supplying objective and scientifically verifiable evidence. Indian courts have increasingly acknowledged the evidentiary significance of DNA analysis, rendering it an essential tool in the administration of criminal justice.¹⁵⁶² As a result, DNA profiling enhances the accuracy, fairness, and efficacy of criminal investigations and judicial processes.¹⁵⁶³

SCIENTIFIC FOUNDATIONS OF DNA PROFILING

DNA profiling relies on the scientific principle that each individual has a distinct genetic composition, with the exception of identical twins. DNA, or Deoxyribonucleic Acid, serves as the hereditary material located within the cells of the human body, containing the genetic instructions that dictate an individual's biological traits. The distinctiveness of DNA allows forensic scientists to differentiate one person from another and confirm identity with a high level of certainty.

The human body consists of millions of cells, each containing a nucleus that contains chromosomes. These chromosomes hold genes, which are the basic units of heredity. Although a large portion of human DNA is the same across all individuals, certain areas show variations that are unique to each person. DNA profiling concentrates on examining these variable regions to create a unique genetic profile. The likelihood of two unrelated individuals having the same DNA profile is exceedingly low, which renders DNA evidence highly dependable for forensic applications.

The scientific credibility of DNA profiling has resulted in its broad acceptance in criminal investigations and legal proceedings. Courts often depend on DNA evidence because it is founded on objective scientific analysis rather than subjective interpretations.¹⁵⁶⁴ Nevertheless, the precision of DNA profiling is contingent upon

¹⁵⁶⁰ National Human Rights Commission, *Manual on Forensic Science Services in Criminal Justice Administration* 42 (NHRC, New Delhi, 2020).

¹⁵⁶¹ Interpol, *Disaster Victim Identification Guide* 11 (Interpol, 2018).

¹⁵⁶² *Krishan Kumar Malik v. State of Haryana*, (2011) 7 SCC 130.

¹⁵⁶³ *Mukesh & Ors. v. State (NCT of Delhi)*, (2017) 6 SCC 1.

¹⁵⁶⁴ David H. Kaye, "DNA Evidence and the Courts", 41(2) *Jurimetrics Journal* 123 (2001).

the correct collection, preservation, and analysis of biological evidence.¹⁵⁶⁵

SOURCES OF DNA EVIDENCE

DNA can be extracted from various biological materials typically found at crime scenes. The primary sources include blood, saliva, semen, hair with roots, skin cells, sweat, bones, teeth, and nail scrapings. Recent advancements in forensic science have also facilitated the retrieval of touch DNA, which comprises microscopic skin cells left behind when a person contacts an object.

The presence of diverse DNA evidence sources greatly improves investigators' capacity to identify both offenders and victims. Nevertheless, the evidentiary significance of these samples relies on effective crime scene management and strict adherence to scientific protocols during their collection and preservation.¹⁵⁶⁶

TYPES OF DNA ANALYSIS

- A variety of techniques are employed in forensic laboratories for the analysis of DNA. The most frequently utilized method is Short Tandem Repeat (STR) Analysis, which investigates specific repeating sequences within DNA that differ among individuals. STR analysis is widely acknowledged as the benchmark method for forensic DNA profiling due to its precision and dependability.¹⁵⁶⁷
- Another significant technique is Y-STR Analysis, which concentrates on genetic markers found on the Y chromosome. This method proves particularly beneficial in sexual assault cases where it is necessary to differentiate male DNA from female DNA.¹⁵⁶⁸
- Mitochondrial DNA (mtDNA) Analysis is applied when nuclear DNA is either unavailable or has deteriorated. Given that mitochondrial DNA is passed down through the maternal lineage and

exhibits greater resistance to degradation, it is frequently used in the analysis of ancient skeletal remains, hair shafts, and the identification of disaster victims.¹⁵⁶⁹

- Contemporary forensic laboratories may also employ advanced methodologies such as Single Nucleotide Polymorphism (SNP) analysis and Rapid DNA technology to improve identification capabilities and expedite investigative procedures.

LEGAL RECOGNITION OF DNA EVIDENCE

The increasing significance of scientific evidence is evident in the Indian criminal procedure. According to the Bharatiya Nagarik Suraksha Sanhita, 2023, investigative authorities are authorized to collect biological samples and perform medical examinations essential for forensic analysis. These regulations promote the utilization of DNA evidence in criminal investigations and reinforce the application of scientific methods in the justice system. Additionally, expert testimonies concerning scientific examinations are acknowledged as pertinent evidence under the Bharatiya Sakshya Adhiniyam, 2023, thus improving the evidentiary weight of DNA profiling in court proceedings.¹⁵⁷⁰

DNA PROFILING PROCESS

DNA profiling is a systematic scientific method used to analyze biological samples in order to create a unique genetic profile for an individual. The process commences with the identification and collection of biological evidence from the crime scene, victim, or suspect. Typical samples include blood, saliva, semen, hair roots, skin cells, bones, and teeth.

- i. The initial phase involves the collection and preservation of samples. Investigators must ensure that biological evidence is collected, packaged, labeled, and transported correctly to avoid contamination or degradation. Effective

¹⁵⁶⁵ *Dharam Deo Yadav v. State of Uttar Pradesh*, (2014) 5 SCC 509.

¹⁵⁶⁶ John M. Butler, *Fundamentals of Forensic DNA Typing* 27-35 (Academic Press, 2010).

¹⁵⁶⁷ *Ibid.*

¹⁵⁶⁸ John M. Butler, *Advanced Topics in Forensic DNA Typing: Methodology* 347-373 (Academic Press, 2012).

¹⁵⁶⁹ *Ibid.*

¹⁵⁷⁰ *Supra* note 32.

crime scene management is vital at this stage, as any errors in collection can impact the accuracy of subsequent analyses.¹⁵⁷¹

- ii. The second phase is DNA extraction, during which forensic scientists isolate DNA from the biological material collected. After extraction, the quantity and quality of the DNA are evaluated through a process known as DNA quantification. This step is crucial in determining whether there is enough DNA available for analysis.
- iii. The subsequent phase is DNA amplification, typically conducted using the Polymerase Chain Reaction (PCR) technique. PCR allows scientists to create multiple copies of specific DNA regions, enabling the analysis of even small amounts of genetic material retrieved from crime scenes.
- iv. After amplification, the DNA fragments are separated and analyzed to create a DNA profile. This profile is then compared with reference samples obtained from suspects, victims, or DNA databases. If the genetic markers align, a match may be established between the individual and the biological evidence.¹⁵⁷²

In conclusion, forensic experts compile a report detailing their findings and conclusions. This report may later be presented in court as scientific evidence. Due to its adherence to a rigorous scientific methodology, DNA profiling is considered one of the most dependable forensic techniques available for criminal investigations.

HANDLING AND PRESEVATION OF DNA EVIDENCE

The precision and dependability of DNA profiling are significantly influenced by the correct handling and preservation of biological evidence.

DNA samples are extremely sensitive and can easily become contaminated, degraded, or

destroyed if not collected and stored properly. Consequently, it is imperative to adhere to strict protocols from the moment evidence is identified at the crime scene until it is presented in court. Effective evidence management not only guarantees accurate forensic analysis but also maintains the evidentiary value of DNA samples during legal proceedings.¹⁵⁷³

Collection of DNA Evidence

The initial step in safeguarding DNA evidence involves proper collection. Biological materials such as blood, saliva, semen, hair, skin cells, bones, teeth, and nail scrapings must be identified and collected using sterile instruments. Investigators should don gloves, masks, and protective clothing to avert contamination. Each sample must be collected meticulously and separately to preserve its integrity and prevent the transfer of DNA between items.

Packaging and Labelling of Evidence

Following collection, DNA evidence must be appropriately packaged and labelled. Biological samples should typically be placed in paper envelopes or bags instead of plastic containers, as plastic can trap moisture and encourage bacterial growth. Each package should include information such as the case number, date and time of collection, location of recovery, description of the evidence, and the name of the collecting officer. Proper labelling is crucial for maintaining the authenticity and traceability of the evidence throughout the investigation.¹⁵⁷⁴

Preservation and Storage of DNA Samples

Suitable storage conditions are vital to prevent DNA degradation. Wet samples should be air-dried prior to packaging to eliminate the risk of mold growth and bacterial contamination. Evidence should be stored in cool, dry environments, shielded from excessive heat, humidity, and sunlight. In some instances, biological samples may need refrigeration or

¹⁵⁷¹ William Goodwin, Adrian Linacre & Sibte Hadi, *An Introduction to Forensic Genetics* 85-92 (2nd edn., Wiley-Blackwell, 2011).

¹⁵⁷² T. A. Brown, *Genetics: A Molecular Approach* 412-417 (3rd edn., Garland Science, 2002).

¹⁵⁷³ National Institute of Justice, *DNA Evidence: Basics of Identifying, Gathering and Transporting DNA Evidence* (U.S. Department of Justice, 2009).

¹⁵⁷⁴ Peter Gill, "Misleading DNA Evidence: Reasons for Miscarriages of Justice", 5(1) *Forensic Science Policy and Management* 1 (2014).

freezing to preserve their quality for future forensic analysis.

Transportation of DNA Evidence

The transportation of biological evidence from the crime scene to the forensic laboratory must be executed with the highest level of care. Samples should be securely packaged and shielded from environmental exposure during transit. Any damage or contamination that occurs during transportation could jeopardize the reliability of DNA analysis. Consequently, it is imperative to adhere to proper documentation and secure handling procedures throughout the transfer process.

Chain of Custody

A critical element of evidence preservation is the maintenance of the chain of custody. The chain of custody encompasses the continuous documentation of every individual who has interacted with the evidence from the moment of collection until its presentation in court. This includes records of collection, transfer, storage, examination, and production of evidence. An unbroken chain of custody affirms the authenticity and reliability of DNA evidence, safeguarding it against claims of tampering or substitution.¹⁵⁷⁵

Prevention of Contamination

Contamination poses one of the most significant risks to DNA evidence. It can arise from improper handling, mixing of samples, or exposure to external biological materials. To mitigate contamination, investigators must utilize sterile equipment, frequently change gloves, avoid direct contact with evidence, and package each item individually. Additionally, restricting access to the crime scene and adhering to standard forensic protocols are vital measures for maintaining the integrity of DNA.¹⁵⁷⁶

Legal Significance of Proper Evidence Handling

The legal significance of DNA evidence is contingent upon the appropriate collection and preservation methods. According to the Bharatiya Nagarik Suraksha Sanhita, 2023, investigative authorities are authorized to gather biological samples for forensic analysis, while the Bharatiya Sakshya Adhiniyam, 2023 acknowledges the relevance of expert scientific evidence in court proceedings. If evidence is tainted, inadequately stored, or mishandled without maintaining the chain of custody, its reliability and admissibility may be contested during trial. Thus, compliance with forensic protocols is vital to ensure that DNA evidence remains trustworthy and legally acceptable.

The collection, preservation, and analysis of DNA evidence are governed by various provisions within Indian criminal law. These regulations promote the application of scientific methods in criminal investigations and guarantee the admissibility of forensic evidence in court.

- According to Section 51 of the Bharatiya Nagarik Suraksha Sanhita, 2023, a registered medical practitioner is permitted to examine an arrested individual when such an examination is likely to yield evidence pertinent to the commission of an offence. This provision facilitates the gathering of bodily substances that may be necessary for DNA analysis.¹⁵⁷⁷
- In a similar vein, Section 52 of the Bharatiya Nagarik Suraksha Sanhita, 2023, empowers a medical practitioner to examine a person accused of rape and allows for the collection of biological samples essential for forensic investigation. These samples frequently serve as vital DNA evidence in cases of sexual offences.
- Moreover, Section 53 of the Bharatiya Nagarik Suraksha Sanhita, 2023, stipulates the medical examination of a

¹⁵⁷⁵ Eurofins Forensics, “Chain of Custody and Forensic Evidence Management”, available at: <https://www.eurofinsus.com/forensics> (Last visited on June 11, 2026).

¹⁵⁷⁶ National Forensic Sciences University, “Best Practices for Biological Evidence Collection and Preservation”, available at: <https://www.nfsu.ac.in> (Last visited on June 11, 2026).

¹⁵⁷⁷ Supra note 32, s. 51

rape victim and permits the collection of biological material pertinent to the investigation. The proper preservation of such evidence is crucial for ensuring accurate DNA profiling and facilitating successful prosecution.

- A notable enhancement is found in Section 176 of the Bharatiya Nagarik Suraksha Sanhita, 2023, which mandates forensic investigation in offences punishable by imprisonment of seven years or more. This provision necessitates the engagement of forensic experts in serious criminal cases and underscores the significance of scientific evidence, including DNA profiling, in criminal investigations.¹⁵⁷⁸
- The evidentiary significance of DNA analysis is further reinforced by Section 39 of the Bharatiya Sakshya Adhiniyam, 2023, which acknowledges the importance of expert opinions in matters related to science, foreign law, art, handwriting identification, and fingerprints. As DNA profiling is a scientific analysis performed by forensic specialists, DNA reports and expert testimonies are pertinent and permissible in court under this provision.
- Moreover, Section 45 of the Bharatiya Sakshya Adhiniyam, 2023 acknowledges opinions regarding electronic and scientific evidence, thereby enhancing the role of contemporary forensic methods in legal proceedings. As a result, DNA profiling has gained considerable evidentiary importance in modern criminal trials.¹⁵⁷⁹

Thus, the appropriate management and preservation of biological evidence are not only scientific imperatives but also legal obligations. Any disruption in the chain of custody, contamination of samples, or breach of statutory protocols may compromise the credibility,

reliability, and admissibility of DNA evidence during a trial.

The Importance of Proper Preservation

The proper preservation of DNA evidence guarantees precise forensic outcomes, bolsters the prosecution's case, aids in the identification of offenders, and helps avert wrongful convictions. Adequate handling procedures safeguard the integrity of biological samples, allowing courts to confidently depend on scientific results. Therefore, the preservation of DNA evidence serves as a critical connection between crime scene investigation, forensic science, and the justice system.

CASE LAWS

The Narborough Murder Case (1986) – United Kingdom

The investigation into the Narborough murder is recognized as the first criminal case where DNA profiling was effectively utilized to identify a murderer. Two teenage girls were killed in Leicestershire, England. Although an initial suspect confessed to one of the murders, DNA analysis later confirmed his innocence. Following this, DNA screening directed investigators to the true perpetrator, Colin Pitchfork. This pivotal case illustrated the dependability of DNA profiling and underscored its significance as a forensic instrument in criminal investigations.

Santosh Kumar Singh v. State (Priyadarshini Mattoo Case)

This case revolved around the rape and murder of Priyadarshini Mattoo. Scientific and forensic evidence played a crucial role in connecting the accused to the crime. The case underscored the increasing significance of forensic techniques in criminal investigations and demonstrated how scientific evidence can bolster the prosecution's case.¹⁵⁸⁰

¹⁵⁷⁸ Id., s 52, 52, 176.

¹⁵⁷⁹ Bharatiya Sakshya Adhiniyam 2023, s. 39 & 45.

¹⁵⁸⁰ *Santosh Kumar Singh v. State through CBI*, (2010) 9 SCC 747.

Krishan Kumar Malik v. State of Haryana (2011)

In this case, the Supreme Court highlighted the critical role of DNA testing in criminal investigations, especially in cases of sexual offenses. The Court noted that when scientific methods are accessible, investigative agencies should employ them to guarantee a fair and effective inquiry. The ruling reinforced the importance of DNA evidence within the Indian criminal justice framework.¹⁵⁸¹

Selvi v. State of Karnataka (2010)

While primarily focused on narco-analysis, polygraph tests, and brain-mapping techniques, the Supreme Court addressed the connection between scientific investigation and constitutional rights. The ruling stressed the necessity of balancing investigative needs with individual rights and personal freedoms, thereby impacting discussions related to forensic evidence and privacy.¹⁵⁸²

In the Nirbhaya Case, DNA evidence was pivotal in supporting the prosecution's narrative and connecting the accused to the crime. The effective application of DNA profiling highlights the necessity of meticulous evidence collection and scientific inquiry in achieving convictions in serious criminal matters. These instances exemplify the growing dependence of courts on scientific evidence and underscore the importance of effective crime scene management and DNA profiling in the pursuit of justice within the criminal justice system.¹⁵⁸³

CHALLENGES OF DNA PROFILING

Despite its scientific reliability and increasing acceptance in criminal investigations, DNA profiling faces several challenges. The efficacy of DNA evidence is largely contingent upon effective crime scene management, sufficient forensic infrastructure, and adherence to legal protections. Numerous practical, technical, and legal issues continue to influence the collection,

preservation, analysis, and application of DNA evidence in criminal cases.

Contamination of Biological Evidence

One of the most critical challenges in DNA profiling is the contamination of biological evidence. DNA samples can become tainted when investigators, medical personnel, or unauthorized individuals come into contact with the evidence. Improper handling, neglecting to wear protective gear, or mixing samples can introduce extraneous DNA, thereby compromising the accuracy of forensic analysis. Contaminated samples may yield misleading results and diminish the evidentiary strength of DNA evidence in court.

Improper Crime Scene Management

The effectiveness of DNA profiling starts at the crime scene. Inadequate securing, documenting, and preserving of the crime scene can lead to the destruction or loss of vital biological evidence. Unauthorized access, environmental exposure, and insufficient evidence collection methods can jeopardize DNA samples before they even arrive at the forensic laboratory. As a result, poor crime scene management remains a significant barrier to effective forensic investigation.

Degradation of DNA Sample

Biological evidence is extremely sensitive to environmental conditions. Exposure to heat, moisture, sunlight, bacteria, and other environmental factors can degrade DNA samples and lessen their viability for analysis. In instances where evidence is collected after a considerable delay, the quality of DNA may deteriorate significantly, rendering accurate profiling challenging or unfeasible.

Lack of Trained Personnel

Effective crime scene investigation and DNA analysis necessitate specialized knowledge and technical skills. However, numerous investigating officers and crime scene personnel do not

¹⁵⁸¹ *Krishan Kumar Malik v. State of Haryana*, (2011) 7 SCC 130.

¹⁵⁸² *Selvi v. State of Karnataka*, (2010) 7 SCC 263.

¹⁵⁸³ *Mukesh & Ors. v. State (NCT of Delhi)*, (2017) 6 SCC 1.

possess sufficient training in the collection and preservation of evidence. Errors made during the initial phases of an investigation can irreparably compromise DNA evidence and negatively influence the results of forensic examinations. Therefore, ongoing professional training is crucial for upholding investigative standards.

Inadequate Forensic Infrastructure

While DNA profiling has emerged as a vital investigative resource, many forensic laboratories still encounter shortages of modern equipment, qualified personnel, and financial support. The limited capacity of laboratories frequently leads to delays in sample examination and the generation of forensic reports. Such delays can adversely affect investigations and extend the duration of criminal trials.

The rising number of cases necessitating forensic examination has resulted in significant backlogs within numerous forensic laboratories. DNA samples may remain unexamined for months or even years before analysis is finalized. Delayed forensic reports not only obstruct investigations but can also impact the rights of both accused individuals and victims by delaying the administration of justice.

The growing application of DNA technology has also led to ethical dilemmas concerning consent, confidentiality, and genetic surveillance. Questions frequently arise about the collection of DNA samples without consent, the retention of genetic data, and the potential for misuse of DNA databases. Balancing the needs of criminal investigation with the protection of individual rights remains a continuing challenge.

Challenges in Maintaining Chain of Custody

The admissibility and reliability of DNA evidence are significantly contingent upon the preservation of an unbroken chain of custody. Any lapses in the proper documentation of evidence handling, transfer, or storage can raise questions about its authenticity. Defense attorneys may contest the dependability of DNA

evidence if there are gaps or inconsistencies in the chain of custody documentation.

Legal and Procedural Challenges

While the Bharatiya Nagarik Suraksha Sanhita, 2023 promotes the utilization of forensic investigations and scientific evidence, the practical application poses challenges. Disparities in investigative methods, the absence of standardized protocols, and inconsistent compliance with forensic procedures can impact the quality of evidence gathered during investigations. Ensuring consistent adherence to legal and forensic standards remains a critical issue.

DNA profiling is a complex scientific procedure that necessitates specialized equipment, trained professionals, and advanced laboratory facilities. The substantial costs involved in establishing and maintaining forensic laboratories often restrict the availability of DNA testing services, especially in regions with limited resources. Consequently, financial constraints may hinder the widespread application of DNA profiling in criminal investigations.

The rapid progress in biotechnology has introduced new challenges concerning the interpretation and management of genetic data. The growing reliance on DNA databases, artificial intelligence, and cutting-edge forensic technologies necessitates robust regulatory frameworks to avert misuse and ensure accountability. As forensic science advances, legal systems must evolve to tackle these emerging issues.

In conclusion, although DNA profiling is one of the most precise and dependable forensic methods available today, its efficacy is affected by various practical, legal, ethical, and technological challenges. Tackling these concerns through enhanced training, improved forensic infrastructure, strict compliance with evidence-handling protocols, and comprehensive legal frameworks is essential.

SUGGESTIONS

To enhance the effectiveness of DNA profiling in criminal investigations, specialized training should be provided to police officers, forensic experts, and crime scene investigators regarding evidence collection and preservation. Standard operating procedures must be strictly followed to prevent contamination and maintain the integrity of biological evidence.

The government should strengthen forensic infrastructure by establishing additional forensic laboratories equipped with modern technologies and adequately trained personnel. Timely examination of samples would reduce delays in criminal investigations and judicial proceedings. Greater implementation of forensic investigation requirements under the Bharatiya Nagarik Suraksha Sanhita, 2023 would further promote scientific methods of investigation.

Appropriate legal safeguards should also be developed to address privacy concerns associated with DNA databases and the storage of genetic information. Clear regulations governing the collection, use, and retention of DNA data would help balance investigative needs with individual rights.

CONCLUSION

DNA profiling has revolutionized modern criminal investigations by providing a highly accurate and reliable method of individual identification. However, the effectiveness of DNA evidence depends largely upon proper crime scene management, which ensures the systematic collection, preservation, and handling of biological materials. Crime scene examination, evidence preservation, and the maintenance of chain of custody collectively determine the reliability and admissibility of forensic evidence.

The increasing recognition of DNA evidence by courts and legislative provisions reflects the growing importance of scientific investigation in the criminal justice system. Although challenges relating to contamination, infrastructure, privacy, and resource limitations continue to exist, effective crime scene management and proper forensic practices can significantly enhance the

quality of criminal investigations. Therefore, DNA profiling and crime scene management together constitute indispensable tools for achieving accuracy, fairness, and justice in contemporary criminal proceedings.

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